U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-276 478

World Weather Program Plan for Fiscal Year 1977

Department of Commerce, Washington, D C

Prepared for

National Aeronautics and Space Administration, Washington, D C

Sep 76

NOAA FORM 25-13
(2-73)

BIBLIOGRAPHIC DATA SHEET

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

1. NOAA ACCESSION NUMBER
NOAA-77120502

2.

3. RECIPIENT'S ACCESSION NUMBER
PB276478

4. TITLE AND SUBTITLE
World Weather Program. Plan for Fiscal Year 1977

5. REPORT DATE
Sept 1976

6.

7. AUTHOR(S)

8. REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Department of Commerce, Department of Defense, Department of State, Department of Transportation, Environmental Protection Agency, Energy Research and Development Administration, National Aeronautics and Space Adm. NSF

10. PROJECT/TASK NO.

11. CONTRACT/GRANT NO.

12. SPONSORING ORGANIZATION NAME AND ADDRESS
Same

13. TYPE OF REPORT AND PERIOD COVERED

14.
100/00

15. PUBLICATION REFERENCE
Department of Commerce, etal, Plan for World Weather Program for Fiscal Year 1977, September 1976. 79 p, numerous illust.

16. ABSTRACT

The World Weather Program is an international effort to provide man with the knowledge and capability not only to understand the atmosphere but also to make available environmental warnings, forecasts, and assessment which contribute to his well-being. The three basic components of the World Weather Program are the World Weather Watch (WWW), the Global Atmospheric Research Program (GARP), and the Systems Design and Technological Development Program. This Plan describes U.S. efforts in each of the components that either directly support or contribute to the World Weather Program goals. The opening section highlights the results of a decade of successful planning and action taken as part of the World Weather Watch, the operational aspect of the World Weather Program. Section 2 discusses the relationship of our national activities with those of other nations cooperating in the World Weather Program. Section 3 provides specific information on the U.S. planned efforts that contribute to or directly support the World Weather Programs goals in FY 1977. A fiscal summary of these programs is contained in the concluding section. (Sinha - OEIS)

17. KEY WORDS AND DOCUMENT ANALYSIS

17A. DESCRIPTORS

*Weather, *Research projects, *Planning

17B. IDENTIFIERS/OPEN-ENDED TERMS

*International cooperation, World Weather Program, World Weather Watch (WWW), Global Atmospheric Research Program (GARP)

17C. COSATI FIELD/GROUP

4B

18. AVAILABILITY STATEMENT
Released for distribution:
Elaine S Downs

19. SECURITY CLASS (This report)
UNCLASSIFIED

20. SECURITY CLASS (This report)
UNCLASSIFIED

21. NO. OF PAGES
80

22. PRICE
PC A05/MF A01

NOAA FORM 25-13 (2-73) SUPERSEDES ALL PREVIOUS EDITIONS.

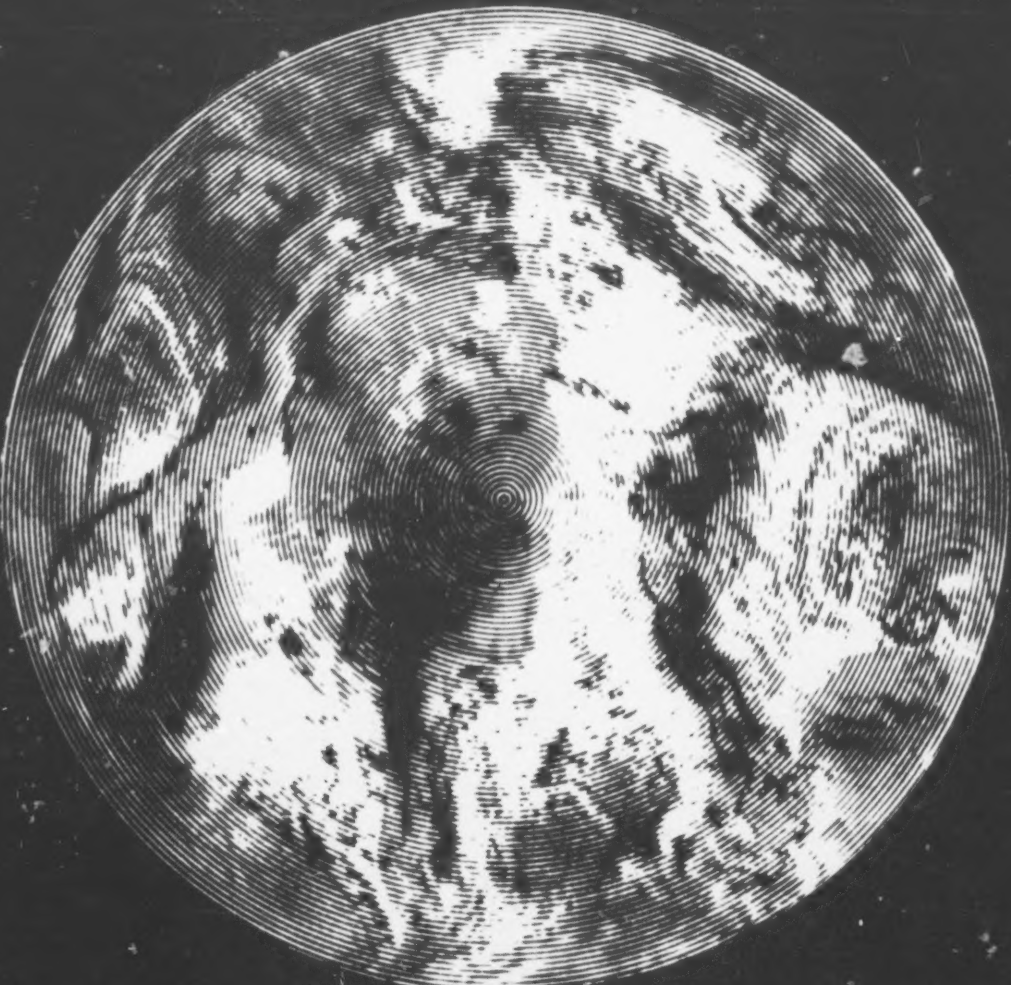
★U. S. GOVERNMENT PRINTING OFFICE: 1975--665077/1124 REGION NO. 6

7712 0502

PB 276 478

WORLD WEATHER PROGRAM

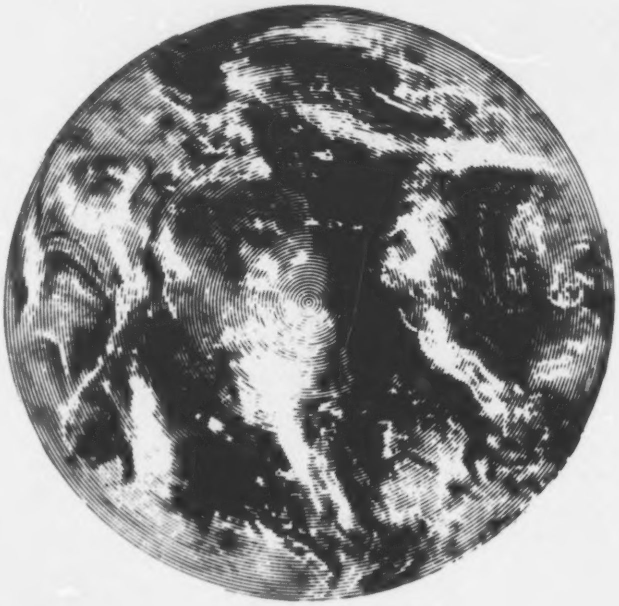
PLAN FOR FISCAL YEAR 1977



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

WORLD WEATHER PROGRAM

PLAN FOR FISCAL YEAR 1977



DEPARTMENT OF COMMERCE
DEPARTMENT OF DEFENSE
DEPARTMENT OF STATE
DEPARTMENT OF TRANSPORTATION
ENVIRONMENTAL PROTECTION AGENCY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SCIENCE FOUNDATION

To the Congress of the United States:

Weather and climate are at once familiar and sources of deep concern. Through technology, we have minimized the harmful effects of weather and have adapted our civilization to a wide range of climatic conditions. Yet, we now know how fragile is the balance between our activities and the environment. Understanding that balance is the key to the successful management of energy, food, and water resources and the beneficial application of technology. Our national goals in improving weather predictions and warnings and coping with the vagaries of climate cannot be accomplished except in the context of a world-wide endeavor. All nations play roles; the United States can be truly proud of our contribuions.

The World Weather Program is the U.S. commitment to an effort that will affect every one of us. I am pleased to report significant and continuing progress in furthering the goals of the World Weather Program. The following accomplishments are representative of the progress being made:

-There has been a smooth transition into the operational use of geostationary meteorological satellites. The Western Hemisphere, much of the Atlantic, and part of the Pacific are now observed continuously. A nationwide network of Satellite Field Service Stations has been implemented by NOAA to capitalize on these new data. Hurricane and typhoon forecasting has been aided, for example, as has the observation, tracking, and warning of severe weather over the United States.

-The data processing system at the World Meteorological Center, Suitland, Maryland, has been expanded through the operational use of a third, fourth-generation computer. This system is essential to handle the improved forecast models and the increased volume of data being received from the World Weather Watch.

-Augmented environmental monitoring and climatic programs have been initiated at the South Pole, American Samoa, and Barrow, Alaska.

-Engineering tests have been completed on large meteorological and oceanographic buoys. The first prototype operational system was moored 240 miles off the Oregon coast. Others are scheduled for operation this summer.

-The initial data-processing phase for the Global Atmospheric Research Program's (GARP) Atlantic Tropical Experiment has been completed and scientific analysis is well underway.

-A series of Data Systems Tests have been completed as a dress rehearsal for the First GARP Global Experiment which starts in 1978.

-The Global Experiment received major impetus when over 40 nations met in February 1976 and agreed to commit ships, buoys, balloon systems, satellites, and other critical facilities for the observational period planned for 1977-1979.

It is with pleasure that I transmit this annual report describing current planned Federal activities contributing to the World Weather Program. The report details how the United States is following the intent of Senate Concurrent Resolution 67 of the 90th Congress to participate in this international program.

Gerald R. Ford

THE WHITE HOUSE,
September 1976

Foreword

The World Weather Program is an international effort to provide man with the knowledge and capability not only to understand the atmosphere but also to make available environmental warnings, forecasts, and assessments which contribute to his well-being. The three basic components of the World Weather Program are the World Weather Watch (WWW), the Global Atmospheric Research Program (GARP), and the Systems Design and Technological Development Program. This Plan describes U.S. efforts in each of the components that either directly support or contribute to the World Weather Program goals.

The opening section highlights the results of a decade of successful planning and action taken as part of the World Weather Watch, the operational aspect of the World Weather Program.

Section 2 discusses the relationship of our national activities with those of other nations cooperating in the World Weather Program. The section describes the updated international four-year plan for implementation of the observing, telecommunication, and data processing functions of the WWW; the assistance to developing countries so they may both benefit from and contribute to the program; the design and management activities for the First GARP Global Experiment (FGGE) to take place in 1977-1979; the results of Data Systems Tests (DST) to permit assessment of the adequacy of the data acquisition, processing, and utilization systems essential to FGGE; and systems design and technological activities for both the WWW and GARP in observing systems, such as new satellites and their sensor systems, wind-finding systems, surface-based remote sensing systems, data buoys, and automatic meteorological observing systems.

Section 3 provides specific information on the U.S. planned efforts that contribute to or directly support the World Weather Program goals in FY 1977. These plans include maintaining a two-spacecraft, operational geostationary satellite system; developing and procuring long-lead time spacecraft and ground equipment for the next generation polar-orbiting satellite system, the TIROS-N; improving programs to monitor atmospheric constituents to determine their influence on climate and their impact upon the quality of the environment; and continuing assistance to developing nations for their participation in the WWW. GARP plans include continued processing, analysis, and interpreting of the GARP Atlantic Tropical Experiment (GATE) observational data and continued planning for the FGGE and for regional experiments designed to provide better understanding of atmospheric processes. GARP research activities are continuing in numerical modeling of the global atmosphere to determine the ultimate limit of weather predictability, assessing the effect of man's activities on climate, and designing an optimum composite meteorological observing system for routine numerical weather prediction.

A fiscal summary of these programs is contained in the concluding section.

All FY 1977 fiscal data in this plan are reflected in the President's budget, and the data shown here should be used for planning purposes only. The scheduling and implementation of the U.S. programs after FY 1977 in support of the World Weather Program are subject to additional analysis and further judgment.

Contents

Page

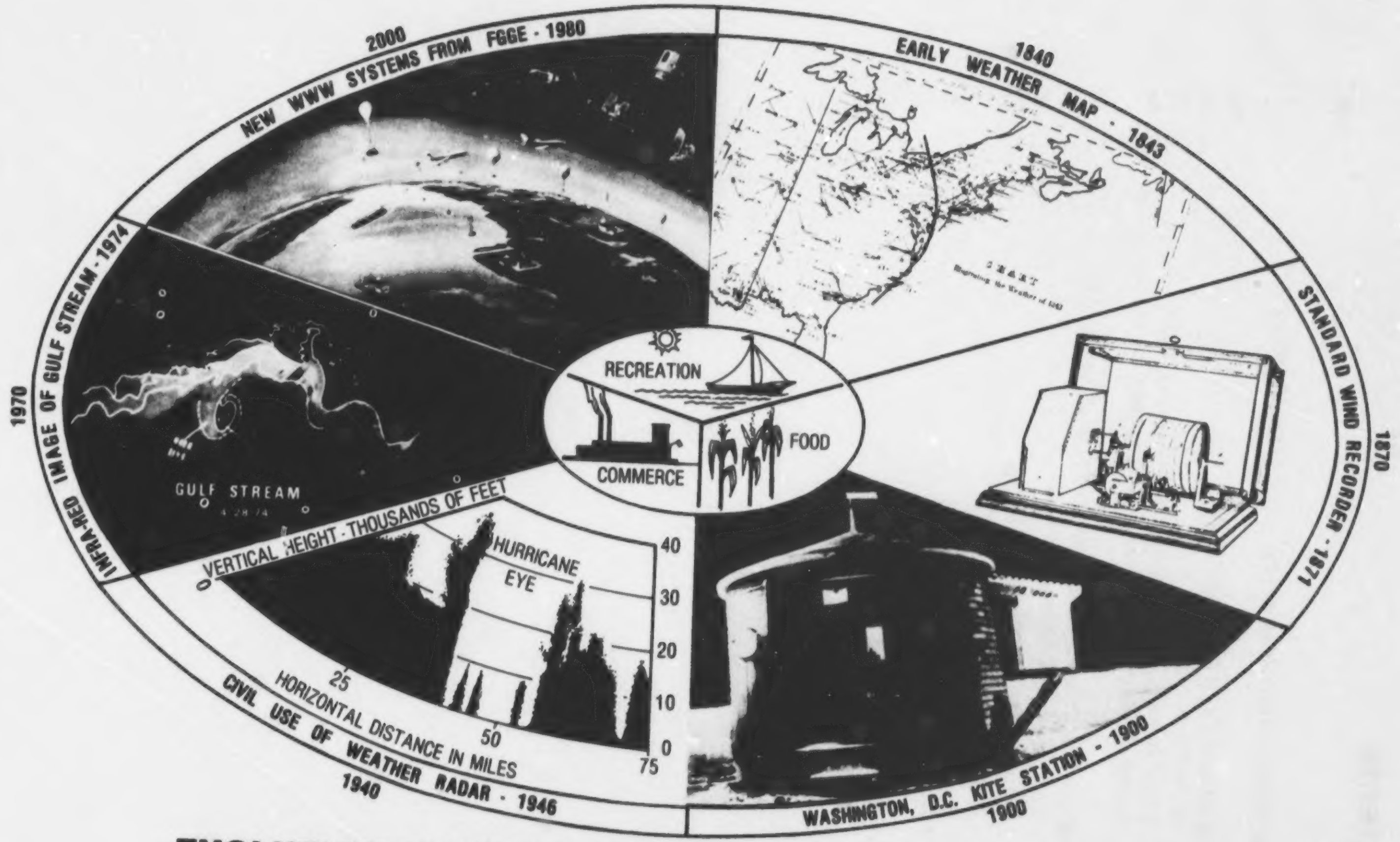
1. THE WORLD WEATHER WATCH – THE SECOND DECADE 1

2. WORLD WEATHER PROGRAM PLAN 24
   World Weather Watch 24
   Global Atmospheric Research Program 42
   Systems Design and Technological Development 54

3. THE UNITED STATES PROGRAM FOR FISCAL YEAR 1977 57
   World Weather Watch Implementation 57
   Global Atmospheric Research Program 60
   Systems Design and Technological Development 64

4. FISCAL SUMMARY 71

APPENDIX – List of Acronyms 72


2000
NEW WWW SYSTEMS FROM FGGE - 1980
1840
EARLY WEATHER MAP - 1843
1870
STANDARD WIND RECORDER - 1871
1900
WASHINGTON, D.C. KITE STATION - 1900
1940
CIVIL USE OF WEATHER RADAR - 1946
1970
INFRA-RED IMAGE OF GULF STREAM - 1974
GULF STREAM
4-28-74
VERTICAL HEIGHT - THOUSANDS OF FEET
HURRICANE EYE
HORIZONTAL DISTANCE IN MILES
0
25
50
75
0
10
20
30
40
RECREATION
FOOD
COMMERCE

EVOLUTION OF METEOROLOGY INTO GLOBAL PROGRAM

1. The World Weather Watch — THE SECOND DECADE

EVOLUTION OF THE WORLD WEATHER WATCH

A Need Recognized

"Nothing but the service of God and the extension of the
monarchy could induce me to expose myself to such dangers again"
Christopher Columbus on Hurricanes

Lacking even a concept of the formation and evolution of storms, captains of the European treasure fleets were forced to repeatedly expose their ships to "such dangers". Over half of those ships lie on the ocean bottom. In 1853 Lt. M. F. Maury (USN) began the first systematic collection and analysis of cooperative observations from sailing ship captains. These data not only defined average conditions but delineated areas of storm formation and their tracks. In that same year the First International Meteorological Conference was held in Brussels, Belgium, emphasizing maritime meteorology. By 1855 Maury was able to estimate from Hunt's Merchants Magazine that his wind and sea charts were saving maritime companies $4,500,000 annually on ship routes between Europe and the Americas.

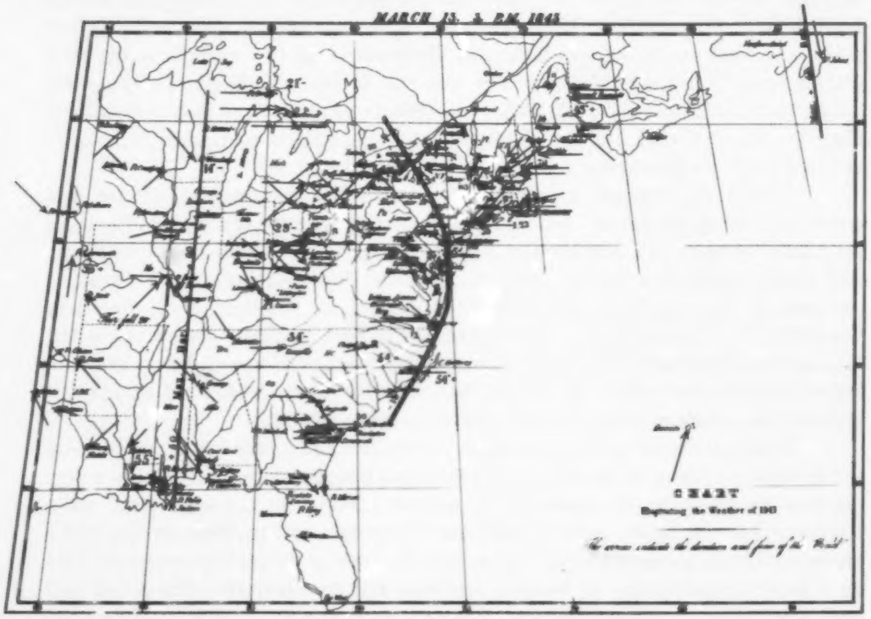
Efforts to forecast weather were spurred by the opening of the first commercial telegraph line in 1845 and early successes were impressive. Weather maps for public use were first published in Washington, D.C. in 1850 based on reports from 150 widely scattered volunteer observers. By 1860 Buys Ballot was using telegraphs routinely to issue forecasts and warnings in Holland. At the time of the American Centennial, U.S. Government weather services had been operating for six years. The International Meteorological Organization, predecessor of the current World Meteorological Organization within the United Nations system, was established in 1873 to facilitate the exchange of weather data and cooperative services.

During the next century, countries modernized, agriculture was pressed to feed the increasing millions of people, and international trade increased dramatically with a resultant explosion in the demands for weather services. At the same time, radio, teletypewriters, facsimile, aircraft, electronic computers, and satellites, in turn had a profound impact on meteorology. These improvements in technology were paralleled by a better understanding of weather processes and the realization that global data were essential to continued advances. However, there was no focus to accelerate the growth of international observing programs, which were slow to use new ideas or technology during the 20 years after WW II. For example, radar was first used for civilian meteorology in 1949 and satellites in 1960, but few countries were using data from either in 1965. Throughout much of the world, techniques developed half a century earlier were pushed to the limit and found to be inadequate.

The inability of many forecast services to cope with critical weather situations had devastating consequences. A tropical cyclone struck Bangladesh in 1970, about 3 months after Texas suffered the onslaught of Hurricane Celia. Effective weather services and timely delivery of warnings to the people kept the death toll from Celia to 11. Deaths in Bangladesh were too numerous to count, but the total was estimated to exceed 300,000.

By the early 1960s, scientists were confident that, if data sources could be improved, programs to forecast global weather were practicable. Meteorological satellites were seen as primary new data sources because they provided one important ingredient that other innovations had not – a global perspective. National boundaries were obliterated in the satellite images, and what remained was the panorama of geography and weather systems. Just as Columbus' voyages gave a global perspective to Old World politics and marked the beginning of a new era, satellites marked the beginning of truly global meteorology.

As exciting as satellite images were, the practical question remained: how to proceed? Satellites could become just another piece of technology in the hands of a few nations or they could be used in concert with other innovations, both technological and scientific, to enhance the effectiveness of global meteorology. The key to progress was an international plan with goals to focus upon and viable procedures for implementation.


MARCH 15. 3. P.M. 1843
CHART
Exhibiting the Weather of 1843
The arrows indicate the direction and force of the Wind

From first report on Meteorology to the Surgeon General of the U.S. Army by James P. Espy, October 1843.

The Plan Evolves

The plan evolved in several arenas. Scientists had already posed questions to be examined and directions to be followed. What was needed was an organization to carry out the work and a spark to get started. In 1961 the United Nations General Assembly adopted a U.S.-sponsored resolution relating to the peaceful uses of outer space. One item in this resolution called upon Members to advance the state of knowledge of the atmospheric processes and to develop meteorological services with worldwide benefits to mankind. United Nations (UN) agencies, including the World Meteorological Organization (WMO), were asked to take steps to implement the resolution. In response, the WMO Fourth Congress approved the concept of the World Weather Watch (WWW) in 1963, and the WWW Plan was formally adopted by the WMO Fifth Congress in April 1967.

In a parallel effort, supporting proposals were drafted and submitted to the U.S. Congress. In May 1968 the Senate passed Concurrent Resolution 67 committing the United States to the World Weather Program encompassing:

–The World Weather Watch.

–A comprehensive program for developing new observation, communications, and data processing techniques.

–A program of research on the atmospheric system.

–A program for training U.S. scientists and technicians.

–A program for providing training and facilities to other nations.

While initial objectives were modest, the plan adopted by the WMO succeeded in laying out the fundamental concepts of a World Weather Watch. Three interlocking global systems were conceived – Global Observing System (GOS), Global Telecommunications System (GTS), and Global Data Processing System (GDPS). The initial four year plan, as has been each subsequent WWW Plan, was supplemented by an implementation program. To guide the implementation, Members, Regional Associations, and WMO Commissions defined their minimum requirements for data. Requirements were combined into Regional Basic Synoptic Networks which quickly became cornerstones in the WWW structure. Deficiencies in networks and facilities were identified and the implementation plan was structured to eliminate the most serious. Each succeeding plan has focused on specific problem areas so new ideas and technology could be brought to bear in a living, evolutionary manner.

A decade after its adoption by the WMO Congress, the World Weather Watch has become an international focus for providing more data, better communications, and improved forecast products and for initiating atmospheric monitoring programs to assess the consequences of mans' pollution.

The World Weather Watch is well past infancy and still developing. Yet, deficiencies remain. What has been accomplished and what are the challenges for the next decade?

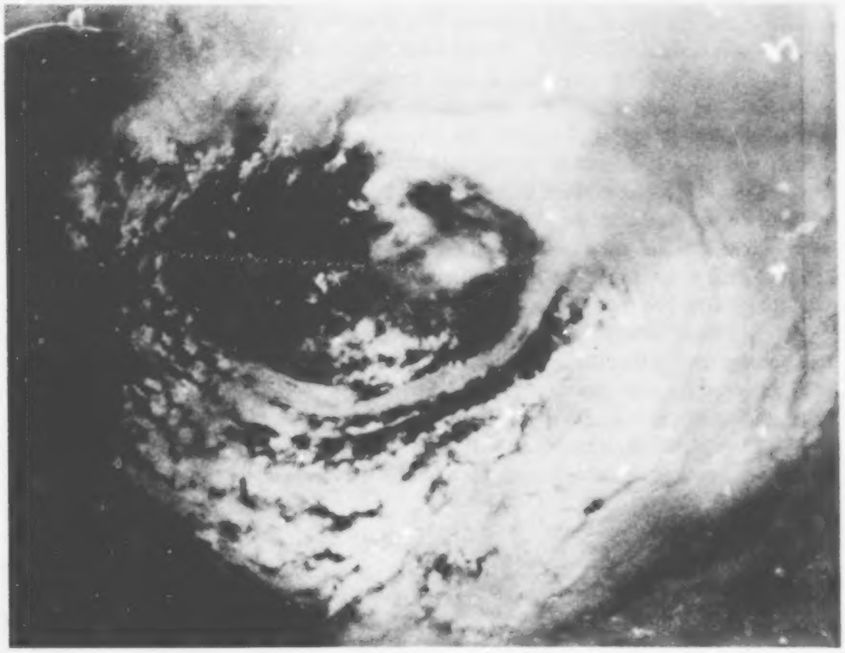
ACCOMPLISHMENTS

A Focus for the World Weather Watch

To further focus the efforts of Members and to reflect the interdependence of global, regional, and national programs, a three-tiered concept was developed and incorporated into the WWW Plan. From the start, national programs were recognized as the responsibility of individual Members. But the thrust of national programs directly affects what can be done regionally and globally. Furthermore, global programs are constrained drastically if they are not supported at the national level. Little is gained, for example, if satellite photographs indicate a major storm to be developing, but the information cannot be communicated to national forecast offices; or once there, cannot be assimilated by the staff. Recognizing that some Members needed financial assistance to begin national programs, the WMO included a Voluntary Assistance Program (VAP) in the original WWW Plan. Through VAP, the most serious deficiencies in developing countries could be met by supplementing national resources with contributions from developed countries. The WWW Plan, augmented by VAP, became the focus for organizing individual efforts, identifying deficiencies, and translating recommendations of the WMO Commissions into coordinated global, regional, and national programs.

Tangible Results

Given the focus, tangible results were achieved in each of the three global systems – observing, telecommunications, and data processing. Some of these accomplishments flowed from a reemphasis in national programs on global needs while others came from a direct application of resources to develop global programs. Two immediate issues needing action at the beginning were (1) gross data deficiencies in the system and (2) initiation of the GDPS.



U-2 image of hurricane Betsy, Sept. 1965. The extent and organization of ocean-generated storms can be determined from aircraft reports and satellite images.

Elimination of Gross Data Deficiencies

The oceans are the largest data-sparse areas and the breeders of most global weather systems. Maury recognized this when he helped found an international organization to collect ship reports, which was the predecessor of the present WMO Commission for Marine Meteorology. Despite this long-standing emphasis, few ship reports appeared on analysts' charts prior to the WWW, except along coasts. Observations were being taken and entered into ships' logs and the data were available for climatology. The difficulty lay in the telecommunications system. While too many ship reports still are lost or delayed, the rate of reception at analysis centers has been increased from 10% to over 25% by persistent efforts to improve the transmission of data. A major problem now is the widespread and time-consuming use of Morse code to send data from ships to shore stations. Techniques for transmitting data at computer speeds using geostationary satellites as relay points are being developed through the cooperative efforts of the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Maritime Commission.

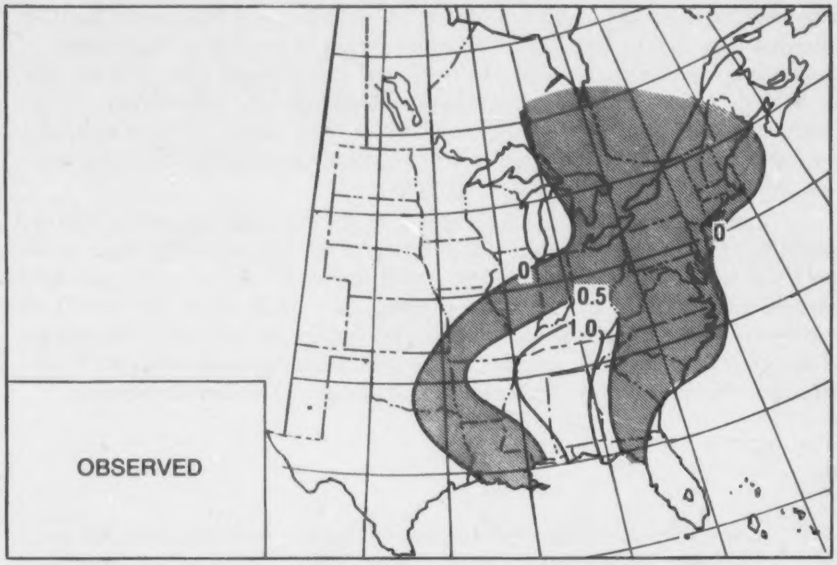
A second gross deficiency was the lack of upper air data over the entire globe, except for parts of Europe and the United States. At the time of the first status report on WWW implementation (1968), about 600 upper air stations exchanged data internationally. Over 700 stations do so now. More significantly, the number of stations taking the required two observations per day has nearly doubled. Virtually all of the increase in upper air soundings from surface-based stations has been in areas other than Europe and North America and most of it as a result of VAP support.

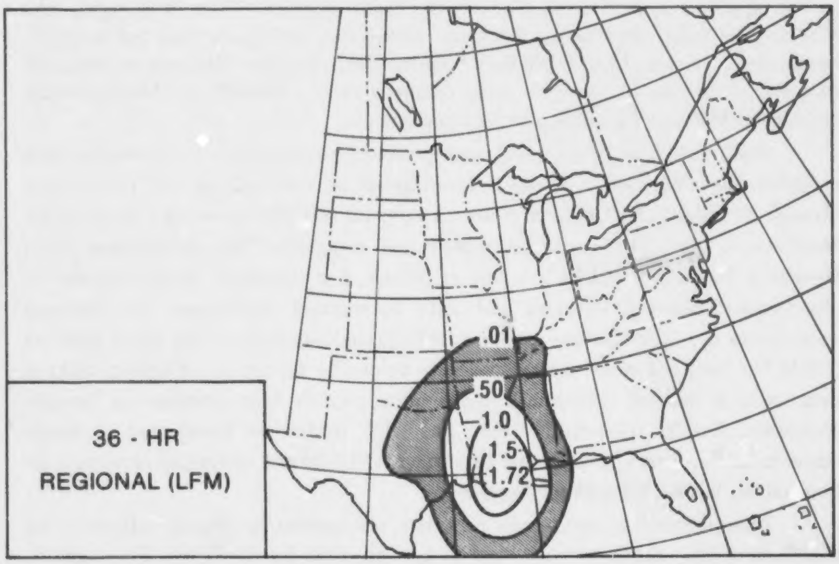
Activation of the GDPS

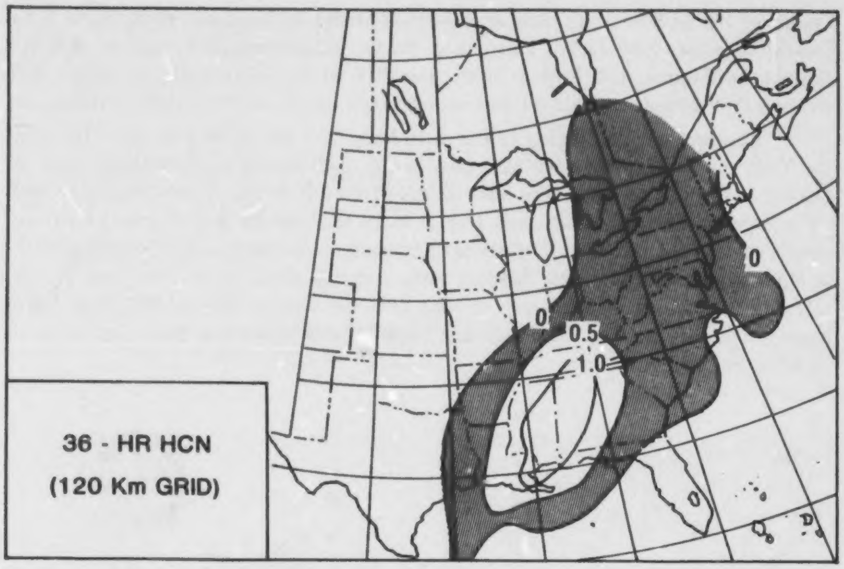
In initiating the Global Data Processing System, three organizational levels were envisioned: World Meteorological Centers (WMC), Regional Meteorological Centers (RMC), and National Meteorological Centers (NMC). Again the tiered aspect to the WWW is evident here. Two of the three planned WMCs, Washington and Moscow, are fully operational. The third, Melbourne, has focused on the Southern Hemisphere. Twenty-three RMCs have been established to provide processed data and forecasts to groups of Members with common needs. Virtually all Members have established NMCs to meet their unique requirements.

Soon the new centers had new products to exchange. In generating new products, there has been a strong interaction between research activities conducted through the Global Atmospheric Research Program (GARP) and work conducted by Members to strengthen national operational programs. The Geophysical Fluid Dynamics Laboratory (GFDL), a part of NOAA, has pioneered research studies on observational network densities and data assimilation techniques. The National Aeronautics and Space Administration's (NASA) Goddard Institute for Space Sciences (GISS) has been active in running studies to determine the impact of various kinds of data. such as vertical atmospheric temperature profiles from satellites, on forecast accuracies. Results from both GFDL and GISS studies are being used to design elements of the First GARP Global Experiment (FGGE) and to develop recommendations on the WWW Global Observing System.

Improvements in operational programs, not necessarily directly related to the GARP, have been another main source of new products for the GDPS. For example, intensive development efforts at the National Meteorological Center, part of the Washington WMC, have resulted in more efficient numerical forecast models that provide greater horizontal and vertical detail. Advanced analysis schemes are now used to accommodate the increasing amount of global data and the varying times of observation. As part of its regional responsibilities, NMC has developed and tested a numerical forecast model for hurricanes that is being used operationally for the first time during the 1976 season.







Forecasts of precipitation accumulation from large scale storms can be improved significantly by using a model newly developed for hurricanes which is also generally applicable. On the left (below) is the forecast of 12-hour accumulations of precipitation made from the current, operational limited-area forecast model (LFM) for December 26, 1975. Isopleths are shown for each 0.5 inches of accumulated precipitation. Left above is the observed pattern of precipitation valid at the forecast time. Above is the forecast made from the new hurricane model (HCN). This model was evaluated in 1975 and is being used operationally for the first time in 1976.

■

Improvements to the GTS

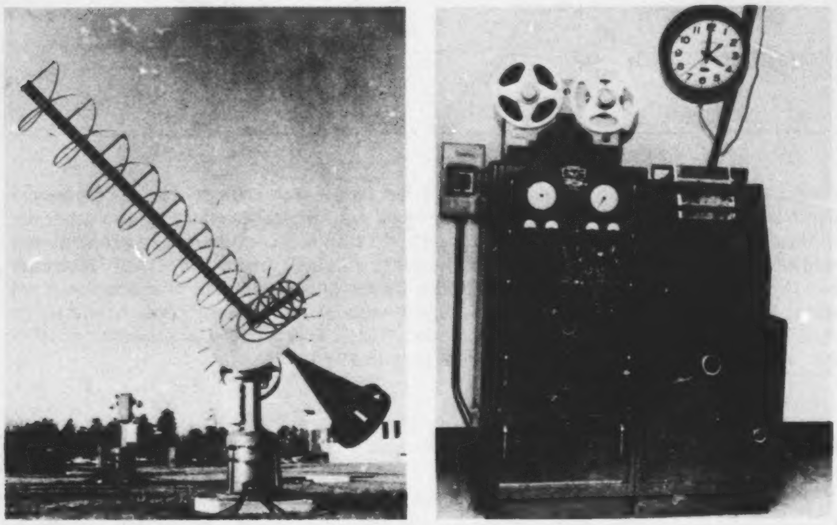
Long before the WWW was initiated, international telecommunications were known to be inadequate. Many of the data and forecast charts were exchanged using techniques at least 30 years old. Radio fascimile was used to transmit charts at the rate of two or three per hour to Europe and Central and South America. Morse code was used extensively to broadcast both data and forecasts. Data were relayed manually from one circuit to another at switching stations. Most teletypewriter circuits operated at 60 to 100 words per minute.

Major advancements have been made since the initiation of the WWW. Even the early progress was impressive. From 1964 to 1968 the number of inefficient Morse code broadcasts dropped from 106 to 52 and the number of point-to-point, or hard-wire, circuits rose from 48 to 76. All WMCs and most RMCs now use computers to switch data between circuits. These computer-to-computer links transmit data at 2400 bits-per-second, nearly sixteen times the transmission speed of the old teletypewriter circuits, and the data are sent with much greater accuracy.

Prior to the implementation of the GTS, data from Africa, South America, and all of the rest of the Southern Hemisphere were seldom received in time to be used in the forecasts prepared by the U.S. National Weather Service. Today the Main Trunk

Circuit of the GTS operates between hubs in Washington, Bracknell, Paris, Offenbach, Prague, Moscow, New Delhi, Cairo, and Tokyo. Major branches reach to Brasilia, Nairobi, Melbourne, and Peking. Now, over 70% of the surface station reports are received in Washington within 3 hours, which meets the deadline for global analysis.

Regional circuits leading to the main hubs have also been improved. Through the VAP, the United States has been particularly instrumental in improving circuits in Central and South America. The Main Trunk Circuit to Brasilia is now supplemented by a Regional Telecommunications Hub at Maracay, Venezuela. Increased data from these circuits have resulted in significant improvement in weather services provided to international air carriers and shipping lines covering these areas. Forecasts of the intensity and timing of hurricanes moving over the Gulf of Mexico also have been improved due in part to the faster and more reliable receipt of data from Central America and Mexico.



Antenna (left) and ground station for receiving Automatic Picture Transmission (APT) images from TIROS satellites. Similar stations are used worldwide as part of the World Weather Watch and many of those were provided through the Voluntary Assistance Program.

Cost of Technology Leads to Shared Facilities

The advances made in the GTS highlight an important issue that had to be faced. New technology, such as computers for switching communications, could be afforded by only a few Members, and no Member could obtain unilaterally all of the global data it needed. Joint ventures and shared facilities are obvious solutions. The United States, for example, makes global forecasts and analyses from its WMC available to all Members. In return, Regional Meteorological Centers and Telecommunications Hubs provide essential buffer services to assemble observational data for the WMCs and to distribute global and regional products to individual Members.

Meteorological satellites are probably the most obvious example of how a few Members can provide facilities for the entire WMO and simultaneously respond to their own national requirements. Both the United States, who launched the first meteorological and geophysical satellites, and the U.S.S.R. provide satellite information to the world. The next three years will see a coordinated venture by the United States, the U.S.S.R., Japan, and the European Space Agency to place geostationary meteorological satellites in orbit. This system of five satellites will provide continuous coverage of the globe between 50°N and 50°S with high resolution sensors. As another example of cooperation, scientists from the United Kingdom have provided instruments for U.S. NIMBUS satellites which have helped obtain vertical temperature profiles of the atmosphere -- a necessary ingredient for accurate weather forecasts.

From the middle 1960's, U.S. TIROS satellites and spacecraft of the Improved TIROS Operational Satellite System (ITOS) have carried Automatic Picture Transmission (APT) equipment for transmitting visual cloud images covering the area within 2500 kilometers of the satellite sub-point. For a very modest investment in APT direct readout equipment, virtually all national meteorological services obtained satellite images of cloud patterns and thus realized some benefits of space-age technology. Several hundred universities and private businesses in many countries also took advantage of this new technology by acquiring APT readout equipment. A whole generation of meteorologists around the world has been trained to interpret satellite APT images. One result has been more accurate and timely warnings of major storm systems, from typhoons over the Pacific to snow storms over the northern United States.

Aircraft have long been an important source of weather information, especially over the Northern Hemisphere oceans. As part of the World Weather Watch and in conjunction with the International Civil Aviation Organization, the United States has conducted a modest program to automate aircraft reports. Automation has the advantage of reducing air-crew work load and human errors, while obtaining observations at more points during each flight. Presently small tape recorders on board selected commercial aircraft are used to collect meteorological data which are delivered to the weather services soon after the aircraft land. Development is underway to obtain an operational system for transmitting automated aircraft observations directly from the aircraft in flight to the weather services via a geostationary satellite. An international test and evaluation program is being organized through the WMO to make the system available for worldwide use.

Computer-controlled telecommunications, satellites, and automation for ships and aircraft require substantial investment in both their development and operation. Where possible, the technology has been shared. One evidence of the value of shared technology has been the ability of both Japan and the European Space Agency to provide geostationary satellites to the WWW in conjunction with the First GARP Global Experiment. Another is the interest shown by several countries in purchasing equipment to automate aircraft reports. The concept of shared responsibility and mutual cooperation fostered by the WWW Plan is leading to a wider and more rapid implementation of the WWW than would be possible otherwise.

■ VAP Provides Seed Money

Developing nations, where additional observations and telecommunications facilities are most needed, are often those least able to afford the equipment. To address this serious problem, Members of the World Meteorological Organization, led by the United States, initiated a Voluntary Assistance Program (VAP) at the outset of the World Weather Watch. Under VAP the WMO identifies deficiencies in the WWW and brings donors and recipients together to eliminate the problem. The purpose of VAP is to overcome the initial obstacles of funding or technology with "seed" money so that developing countries can help themselves.

The VAP program is divided into three parts: equipment and services, cash fund, and training. Equipment and services are provided from donor to recipient through the Secretary-General of the WMO. Activation of new upper air wind-finding stations is an excellent example of introducing new and proven technology into the WWW through the equipment assistance portion of VAP. The classic technique using a balloon-borne radio transmitter for obtaining upper air wind and temperature data was developed in the 1920s and applied worldwide during the 1930s. Modernized versions of these were used by the United States in the early VAP projects in countries such as Algeria, Bolivia, Burma, Colombia, Costa Rica, Ghana, Guatemala, and Mexico. In the 1960s, a lightweight, solid-state radar was developed for obtaining upper air wind data. These wind-finding radar systems are being provided by the United States through VAP to newly activated upper air sounding stations, especially in the tropics where upper wind data are by far the most important to obtain. Recently, Brazil, Guinea, Mauritius, and Senegal received radar wind-finding systems through U.S.-funded VAP projects.

In addition to the equipment, VAP support for upper air systems normally includes a one-year supply of expendables such as balloons, helium (or hydrogen generators), and radiosondes. Thenceforth, the recipient country is expected to support the station totally. Training is provided by the donor country so that all recipient countries can man the stations from the outset. Through a combination of individual donor support and the cash fund of VAP several roving electronics technicians are provided to help the countries keep the equipment operating. The United States helps to support such a person in South America.

As part of VAP equipment and services, the United States has provided psychrometers, aneroid barometers, and instruments for measuring sea-water temperature to equip 30 Greek merchant ships. In addition, approximately 40 nations including the United States provide Port Meteorological Officers who visit ships in port to calibrate and clean instruments, instruct observers, replace observing forms, and collect logs of weather observations. These services, although not a part of VAP, are necessary to keep the VAP equipment functioning and exemplify how the various programs complement each other.

New surface observing stations have been installed under VAP; others destroyed by flood and earthquake have been replaced. The United States provided equipment to Guinea for nine stations and to Sierra Leone for two. In addition the United States restored four observing stations in Honduras after the 1974 hurricane and helped to restore the Honduran national meteorological telecommunications system and the national meteorological center.

By and large, however, telecommunications and upper air observation stations have been the most active areas for VAP support with equipment. The United States and the VAP cash fund provided telecommunications equipment to complement the Netherlands' offer of a computer-based switching system for the establishment of a Regional Telecommunications Hub at New Delhi, India. Burma is improving its national collection network with equipment and services provided by the United States. The Regional Telecommunications Hub that was established at Nairobi, Kenya, with Sweden's donation of an automatic telecommunications switching system is being improved with telecommunications equipment provided by the United Kingdom, the VAP cash fund, and the United States. Upper air stations in Indonesia and Gabon are being established either wholly or partly through U.S. VAP assistance. These are only a small sample of the telecommunications and upper air observation station projects undertaken.

At times the total transaction cannot be completed by the donor. When this occurs, the second part of VAP, a cash fund, is used to augment the donor's contribution. This cash fund, VAP(F), is provided directly to the Secretariat, which, with the Executive Committee of the WMO, decides how the money is to be spent. About 10% of the U.S. VAP input goes to VAP(F).

The third part of VAP is training, both long- and short-term. Sixty-eight countries have each received one or more long-term fellowships under VAP. The United States usually provides four to six fellowships each year for training in this country. In 1975 the WMO Secretariat polled all prior recipients of VAP long-term fellowships and found that 93% were actively engaged in the environmental sciences. In 1975 the WMO Executive Committee endorsed the concept of short-term training, primarily on specialized topics. The first short-term training course was on interpreting meteorological satellite data, and it was held early in 1976 in the Netherlands Antilles with instructors from the United States.

■ WWW Focused Scientific and Technological Developments

The World Weather Program Resolution adopted by the U.S. Congress recognized that the program should go beyond the utilization of proven technology to achieve immediate improvements to the WWW. In addition, the concept foresaw a cooperative international program to develop and test new technology, procedures, and techniques for the WWW. During the course of the first decade of the WWW, three areas were highlighted with new technology: (1) increased upper air data, both winds and temperatures, (2) increased oceanic data, and (3) improvements to the efficiency of the GTS.

■ Increased Upper Air Data

Meteorological satellites, both the polar-orbiting TIROS and NIMBUS series and the more recent Geostationary Operational Environmental Satellites (GOES), have contributed substantially to the availability of temperature and wind data. The first instruments for making temperature soundings from space were flown on NIMBUS research satellites in 1969.

The current operational system used on the ITOS/NOAA satellites selectively receives infrared radiation from several (up to eight) layers in the atmosphere and from the surface. These radiation observations can be converted into a vertical profile of temperature in the various layers where the radiation originates. Hundreds of profiles can be obtained globally on each orbit. While not as detailed in vertical structure as data from surface-based sounding systems (such as the radiosonde) nor as yet as accurate, satellite-derived temperature profiles provide data to numerical models over vast areas where no other data exist.

GOES satellites, each remaining over one geographical point above the equator, provide images over a large fraction of the earth's disk, every half hour or less. The resolution can be as detailed as 0.9 kilometers. At this resolution small cloud clusters and even individual thunderstorms can be identified and monitored. By tracking cloud patterns between successive images, wind fields can be inferred. Automatic techniques to obtain wind data have been developed by NOAA, the University of Wisconsin, and others. Several thousand wind reports so obtained are entered onto the GTS daily.

Increased Oceanic Data

Satellites are also an invaluable source of oceanic data. Sea-surface temperatures are derived from radiometer data and analyses are prepared routinely for distribution over the GTS. The major ocean currents, such as the Gulf Stream, can be delineated as can significant deviations from normal paths. Areas of upwelling, where nutrient-rich bottom water surfaces, are also observed. These regions are particularly rich in fish. Consequently, U.S. marine meteorological services to the shipping and fishing industries have been improved significantly and the availability of satellite data is an important reason.

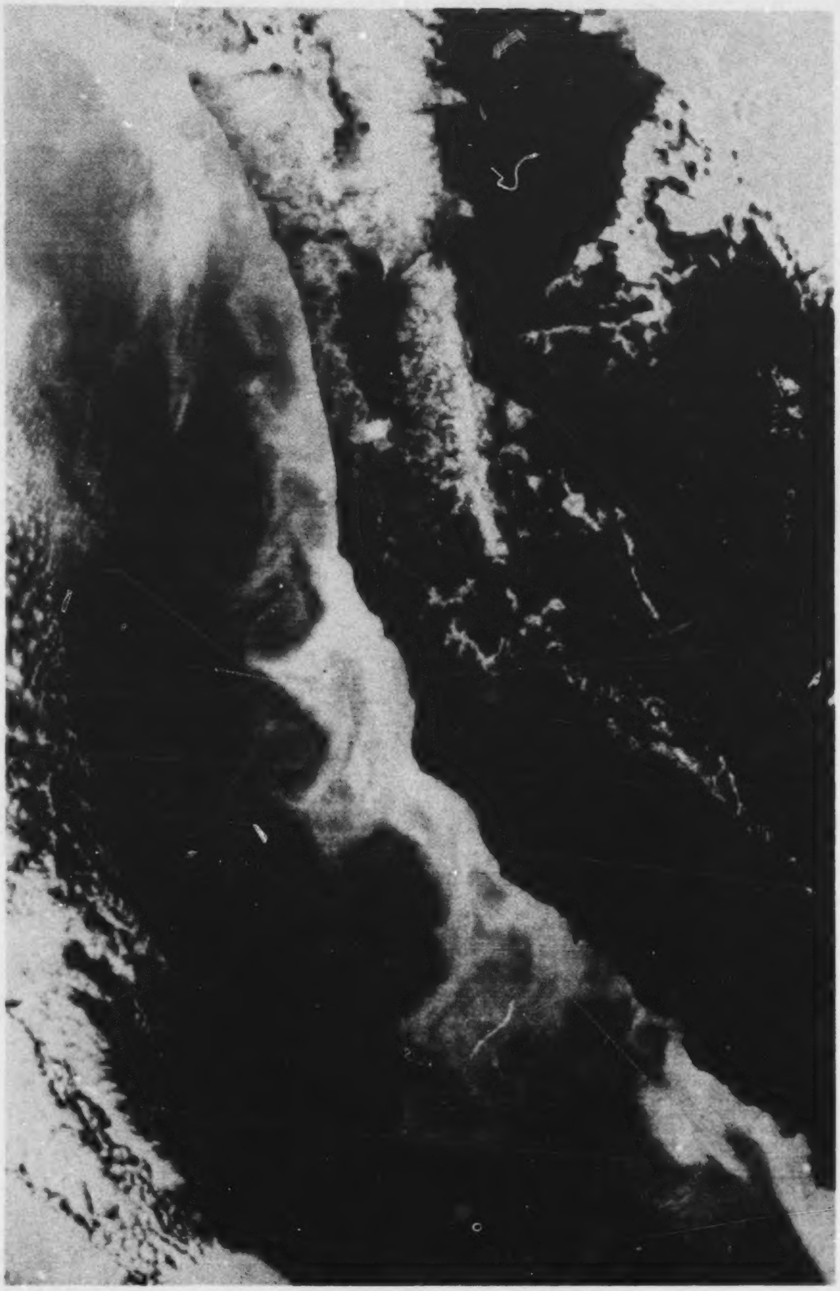
As important as satellites are, they are not meant to replace other techniques. However, they can be used in tandem with other techniques to vastly improve the overall efficiency of the WWW in obtaining and using marine data. Despite improvements in data handling and transmission, almost 75% of the ship observations potentially available are not received at processing centers in time for use in analyses. The major bottleneck is the ship-to-shore communications procedure. Receiving stations can handle only six or seven reports each hour because Morse code is used and shipboard radio operators provide only limited shift coverages. A device called the Shipboard Environmental Data Acquisition System (SEAS) has been developed for use on merchant ships and is to be evaluated by the Department of Commerce during the coming year. SEAS will collect data on wind, atmospheric temperature and pressure, and sea-water temperature and salinity automatically from sensors mounted on the ships. These data will be formatted and transmitted on schedule to a GOES satellite. From there, the data will be relayed to a ground receiving station and placed into the GTS. Except for entering the ship's position and speed into the SEAS module, the entire process is automatic. With the new system the quality of data will be improved (wind is estimated at the moment on most ships and salinity is not observed at all) and the delay at the shore stations will be bypassed.

Expendable bathythermographs (XBTs) provide another new source of oceanic data. These devices sample temperature and salinity to depths of 500 meters and relay the data through a trailing wire back to the launching ship. Some 100 ships worldwide are now equipped with XBTs, and the data are carried on the GTS.

Moored buoys have just recently become an important part of the marine observing system. The U. S. development program was conducted jointly by the Department of Commerce and the Department of Transportation. As U. S. Coast Guard light ships became increasingly costly to maintain and operate, large navigational buoys were developed to be used in their place. These buoys are excellent platforms for obtaining surface atmospheric and oceanic data as well as routine profiles of the water to depths of 500 meters. Each three hours the data are relayed to shore stations and from there to the GTS. One prototype system is operational and eight other experimental buoys are scheduled to be retrofitted for operation this year.

Further Improvements to the GTS

Computer switching of data has already been identified as a major improvement to the GTS acccomplished since its inception. As with observations, satellites



Infrared image from NOAA-3 satellite showing areas of upwelling immediately adjacent to the California-Oregon coast. Water temperatures are indicated by the shading with the coldest water in areas of upwelling being the lightest shade. Warmer water (dark shading) is indicated near the band of clouds in the lower left corner.

An expendable bathethermograph, similar to those used on merchant ships, being launched from the National Marine Fisheries Service vessel **DAVID STARR JORDAN.** The probe carrying the sensors can be seen in midair at lower left. The signal wire is too fine to be seen.

have provided important improvements to global telecommunications. Collection by satellites of data from platforms such as ships, buoys, aircraft, and remote stations represents an improvement both to the GOS and GTS.

More closely related to communications are Weather Fascimile (WEFAX) broadcasts from GOES. Satellite images contain an extremely large amount of data, especially GOES images with their fine resolution. The GTS cannot at this time handle the distribution of any significant number of these images. Further, mosaics of images from polar-orbiting satellites are also available for distribution. During part of each day the United States broadcasts satellite images, mosaics, and a few other products over WEFAX. Any country with the proper equipment in the 120° longitude sector under the GOES satellites and in the belt between roughly 70°N and 70°S can receive these transmissions.

The United States and Japan are developing a high speed, digital fascimile link to increase dramatically the capability of that part of the GTS. Scheduled for operation in 1978, in time for the First GARP Global Experiment, the system will be able to digitize satellite images and transmit them with little loss of quality. This new technique will extend greatly the ability of nations to exchange and receive graphical products of all kinds.

■ WWW-A Platform for Expanded International Programs

Important progress has been made in planning and designing the WWW during its first decade, and modest success has been achieved in implementing a coordinated observing system, an effective telecommunications system, and a data processing system using some of the largest and fastest computers available. The WWW is the only complete system of this scope in the United Nations' structure. Consequently, designers of new environmental programs of the UN have looked to the WWW either as a model or for support.

One such program is the Integrated Global Ocean Station System (IGOSS) which is directed by the Intergovernmental Oceanographic Commission (IOC), a part of the UN Educational, Scientific, and Cultural Organization (UNESCO). The IGOSS objectives relating to the world's ocean system are similar to those of the WWW for the atmosphere system. Since the oceans and the atmosphere are directly coupled in terms of exchanges of heat, moisture, and momentum, oceanic data needed for meteorology are also needed for oceanography. A joint IOC/WMO Planning Group for IGOSS is responsible for coordinating requirements for these data and overall activities of the two groups. GARP and its subordinate research projects, such as the Barbados Oceanographic and Meteorological Experiment (BOMEX), GATE, and FGGE, are deeply involved with oceanic processes and have provided direct input to IGOSS planning. A practical consequence is that certain IGOSS requirements for data have been incorporated into the WWW Global Observing System. Examples are surface and subsurface salinity and temperature data, which are moved over the GTS using a jointly developed code. In addition, close cooperation is maintained between IOC and WMO on the subjects of ocean currents, marine pollution monitoring, and marine environmental data storage.

Increasingly, there is a major international concern over a broad spectrum of environmentally related events including pollution, drought, earthquakes, climatic change, insect infestation, and major changes in the state of the oceans. One hundred thirteen nations met in Stockholm, Sweden, in 1972 to translate this concern into an action plan to preserve and enhance the human environment. The UN Environment Program (UNEP) emerged with EARTHWATCH as the assessment portion. The aim of the UNEP is to fill critical needs not now being met by specialized agencies.

Cooperating with UNEP in EARTHWATCH are the WMO; Food and Agriculture Organization (FAO); United Nations Educational, Scientific, and Cultural Organization (UNESCO); and the World Health Organization (WHO). EARTHWATCH was designed as a four-pronged program involving (1) monitoring, (2) research, (3) evaluation, and (4) information exchange. Several of the goals approved for EARTHWATCH focus on WWW-related problems such as an assessment of global atmospheric pollution and its impact on climate and an improved international disaster warning system.

Earthquakes, such as that which occurred in Alaska in 1964, are of concern to the UN Environment Program EARTHWATCH, which will make use of World Weather Watch facilities for observing, data processing and telecommunications.

A Global Environmental Monitoring System (GEMS) has been proposed as the monitoring segment of EARTHWATCH. To do the job, EARTHWATCH and GEMS plan to make use of the observing, processing, and telecommunications systems of the WWW.

In summary, many factors are responsible for the expanded international coordination and cooperation in environmental programs and the progress that has resulted. The WWW has played an important role in supporting the broad scope of environmental programs being addressed by the UN. Some programs, such as VAP, are uniquely a part of the WWW. For others, the WWW provided the cohesive force binding together diverse activities and thereby providing a platform for more extensive and coordinated programs. Finally, the WWW is a continuing stimulus to individual nations to improve their own meteorological and oceanographic services.

Climate changes, natural and man-made, can have devastating effects on food supplies. Here, cattle try to feed on land which has been turned into a dust bowl by overgrazing. EARTHWATCH and the World Weather Watch have coordinated goals aimed at both understanding the basis for climate changes and improving the international disaster warning system.

CHALLENGES FOR THE SECOND DECADE

Despite the significant accomplishments of the World Weather Watch, major challenges remain to be faced in the coming decade. Foremost among these are:

–Developing procedures for performance evaluation and control,
–Applying the WWW effectively to new, global programs, and
–Developing a far-sighted plan for the future.

Performance Evaluation and Control

The WWW is an amalgamation of facilities and equipment operated by people through the meteorological services of 145 Members and the WMO Secretariat. With so many diverse elements involved, continued performance evaluation is essential to maintain a steady rate of improvement in the overall operation. A concerted monitoring effort has potential for producing as much additional usable data at processing centers as will newly added conventional observing systems.

Yet, this potential cannot be tapped effectively as current techniques to evaluate the performance of the WWW are not adequate to isolate the source of many failures. As a result, the data loss in some WMO Regions remains high, one third or more. To remedy the situation, techniques for evaluation and control must be developed and resources to do it must be provided.

The WMO's Commission for Basic Systems (CBS) already has made a study of the resources needed for systematic monitoring of the performance of the WWW. A plan has evolved and will be presented for consideration in November 1976. With the help of experts from many nations, including several from the United States, the WMO Secretariat has begun a pilot program which will lead to implementation of the CBS monitoring and evaluation plan.

The pilot program is to include "traffic expediters" who will operate under the aegis of the WMO to evaluate computer-prepared summaries of data received at processing centers. Patterns of late, incomplete, or missing data will be identified and the source of the failure isolated. Regional Associations and specific Members will be informed of failure patterns by the WMO Secretariat so that action can be taken. In the case of equipment failure, circuit-rider electronics technicians can be sent to help. The present cadre of such technicians will be expanded to provide more service. Other proposals, such as training for Port Meteorological Officers to increase the quality and quantity of ship reports, will be evaluated and implemented when feasible.

Embedded in the question of efficiency is the impact of new technology. New computers and forecast models are placing new demands on the entire WWW system. At the same time, the application of satellite data, introduction of surface-based indirect sensing techniques such as LIDAR (laser-type radar), operation of denser networks of wind-finding radars, and other observing improvements will continually change the characteristics of the data base. This continual flux of ideas and technology over the next decade presents a formidable challenge. What is the best mix of systems? How much data is enough for the forecast models? It is important to ensure that the observing program does not become decoupled from the needs of new service programs and advanced forecast techniques.

Here is where the First GARP Global Experiment (FGGE) has strong interaction with the operation of the WWW. In preparation for FGGE there has been a series of Data Systems Tests (DST). Lasting one to two months each, these tests stimulated special efforts to obtain and process all of the data possible from the WWW. The results of the DST analyses are having an important effect on the WWW implementation because they are focusing more clearly on specific deficiencies in the system performance. A more significant impact of the FGGE DSTs on the WWW, however, is that studies are being run with and without data from various observing systems such as satellites and radiosondes to determine the effect on the resultant forecasts. The results of these and similar studies are being used to design the FGGE and to restructure the WWW where important deficiencies become evident.

■ Applying the WWW Base

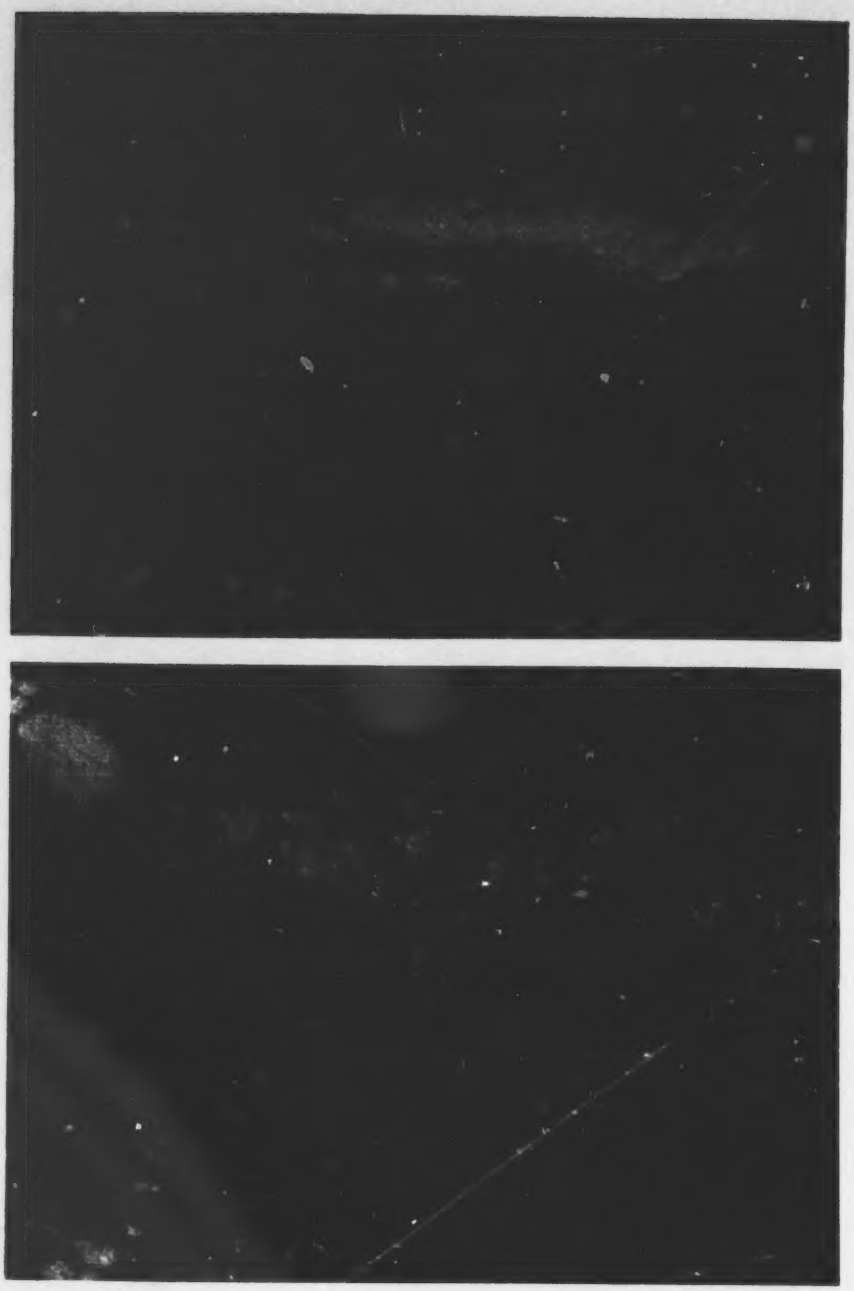
The first decade has been one of pulling together partially completed segments to form the Global Observing, Telecommunications, and Data Processing Systems. Modernization, acquisition of new equipment, and training have been the stimuli keeping the WWW moving forward.

Prospects for continued advancement in the second decade are excellent; however, the character of the programs is changing in response to the new stimuli of EARTHWATCH, climate dynamics, and geophysical monitoring. For example, understanding the physical basis of climate was identified as the "second objective of GARP" in 1967 when WMO and the International Council of Scientific Unions (ICSU) concluded the agreement on GARP, and the WWW was tasked as the major system to provide the needed data. Considering the scope of these new programs in terms of time scales, range of disciplines, and the impact on all living things, a real danger is overcommitting WWW facilities and human resources. A critical challenge to the WWW is to balance the developing capability arising from new technology, new forecast models, and new insight from GARP with the requirements of these and other new programs directed toward the problems of fundamental concern to mankind; food, water, energy, and environmental quality.

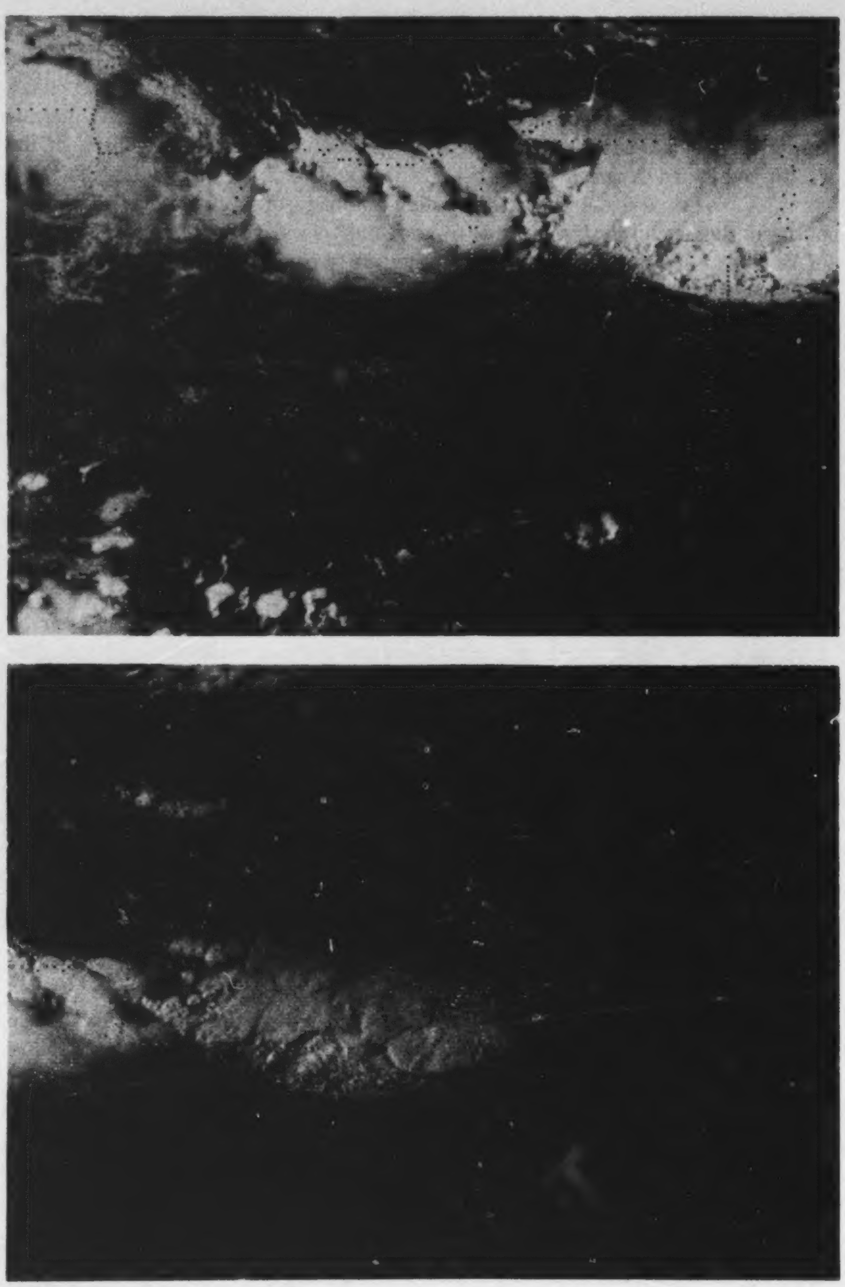
To keep problems tractable, one strategy will be to place more emphasis on regional programs where issues can be focused. Several technological developments are contributing to this change in emphasis so that important starts can be made on the regional aspects of global problems. Long-range weather radars with coverage extending out to 460 kilometers can provide quantitative information on precipitation occurrence and amount. Such quantitative information on the areal distribution of rainfall is fundamental to devising effective programs for water management and flood forecasting and control, and eventually providing a basis for localized weather modification. Since the weather processes involved rarely are limited to one nation, a coordinated regional effort is necessary. An example of regional cooperation in the formative stages is a network of storm detection radars from the Philippines through Southeast Asia to Pakistan to provide detailed information on the intensity of tropical cyclones which regularly devastate those areas.

Another technological development is the increased availability of relatively low-cost, automated meteorological stations. Dense surface networks over limited areas can be employed to provide detailed information on regional storms to augment the areal coverage of radars. Data from automatic stations are particularly important for continuously monitoring conditions in remote areas, for immediate weather forecasting, for hydrologic forecasting, and for determining climatic regimes.

Environmental satellites have already provided a basis for developing regional programs. As a result of closely spaced disasters in 1970 due to tropical cyclones and associated flooding in Bangladesh and elsewhere in Southeast Asia, a Tropical Cyclone



Severe convective activity is shown south of Lake Ontario in this sequence of four GOES images taken on July 3, 1975. Beginning at 1200 EDT (top), outflow from the thunderstorms has formed an arc line immediately south of the eastern half of the system. By 1700 EDT (bottom) the arc line has triggered new storms and is moving south through New Jersey, Delaware and Maryland at 60 MPH.



The above two images were taken at 1730 (top) and 1800 EDT. During this half hour, two intense thunderstorms formed on the arc line in central and western Maryland. Winds recorded along the Chesapeake Bay exceeded 55 MPH. as the arc line passed. Regional GOES direct readout stations which would use sequences like these are being considered for inclusion in the WWW as an aid to improving warning and forecast services.

Project was established by the WMO. Developing techniques to identify tropical cyclones and to estimate their intensity from satellite images is the key part of this project. The United States regularly provides advisory bulletins on all tropical cyclones viewed by its satellites, and the procedures used to determine intensity and forecast tracks will be a foundation for expanding regional programs covering parts of the Pacific and Indian Oceans.

To date, regional services including warnings of cyclones have relied on polar-orbiting satellites which provide coverage only twice per day at most for any part of the globe. At this frequency significant phases of development can be missed, and misleading impressions can be obtained of the state of development or intensity. Geostationary meteorological satellites provide continuous coverage in their field of view, both day and night. The system of five such satellites to be operated at least through the end of FGGE (1979) by the United States, the U.S.S.R., Japan, and the European Space Agency can provide data for issuing forecasts and warnings as part of a series of regional programs.

In addition to providing exciting opportunitites, the availability of satellite data also presents problems of effective utilization. Because of the potentially high volume of data available from satellites and the complexity of the GOES ground system, not all countries are able to afford receiving and processing equipment. Also because of the volume of data, it is not practical to transmit globally all of the details that make geostationary satellite data so valuable. An alternative approach is to establish a series of regional readout stations which could obtain data directly from the satellite, process them, and distribute products and analyses to adjacent countries. The feasibility of such an approach is being examined, and the WMO will sponsor a regional meeting during the coming year to consider how such a system of stations might be established. These direct readout stations would also be the nucleus of regional programs integrating support for a wide range of activities including oceanography, hydrology, and environmental monitoring as well as meteorological forecast and warning services.

A particularly difficult task will be to sift and combine requirements from the diverse programs so that the most essential data can be obtained, transmitted, and processed. Coordinated requirements among the WMO, UNESCO, UNEP, and other UN programs coupled with a regionalization of programs will do much to let the WWW respond to the increasing demand to deliver more data to more places in a shorter time. But in applying the WWW to meet its global obligations, we cannot simply add more of the same or indiscriminately add new technology. Instead, we must make more effective use of technology in the redesign of the WWW to expand its capability and increase its efficiency.

Plans for the Future ■

In the formative first decade, operational experience was the only guide for planning the WWW. Obvious things had to be done to create both its form and content. The maturing of the WWW in the second decade will be largely the result of applying the system and improving it with new technology.

Plans for the next decade of the WWW will be influenced greatly by the results of FGGE. A maximum effort will be made during two FGGE special observing periods in 1979 to obtain the most data possible from both special observing systems and the WWW. These data will be used to examine the mix of conventional and advanced systems, the distribution of data points, and techniques to assimilate information into the data base. The performance of current forecast models will be examined in detail and new models developed which will capitalize on the improved data base.

For the first time a systematic set of scientific studies, on a global scale, will be available to temper both operational experience and the promise of new systems. The greatest challenge will be to use that unique combination of scientific knowledge, operational experience, and technological promise to structure the WWW Plan for the future.

An artists view of FGGE Observing Systems. The buildup phase for the First GARP Global Experiment will begin in late 1977. The year long observing period will begin in September 1978 and include two 60-day intensive, Special Observing Periods. New surface-and-space based systems will augment the World Weather Watch programs. One result of FGGE will be recommendations on the future design and operation of the WWW.

2. The World Weather Program Plan

The World Weather Program provides the mechanism among the nations of the world for integrating activities directed toward improved weather and hydrologic services and environmental quality. The goals of the World Weather Program focus on extending the range and scope of weather forecasts, understanding the bases of climate and climatic changes, assessing the consequences of man's activities on the global atmosphere, and examining the feasibility of large-scale weather modification. This section reports on the U.S. progress, in conjunction with other nations of the world, in implementing the major elements of the World Weather Program. These elements are the World Weather Watch (WWW) and the Global Atmospheric Research Program (GARP), both of which are supported by the System Design and Technological Development program.

WORLD WEATHER WATCH ■

The World Meteorological Organization, a specialized agency of the United Nations with 145 Members, coordinates the international planning and implementation of the World Weather Watch. The international World Weather Watch Plan is updated in four-year cycles to coincide with the WMO financial period and the meetings of the WMO Congress. In 1975 the Seventh WMO Congress approved the WWW Plan for the period 1976-1979.

The World Weather Watch is designed as an integrated global system consisting of observing, telecommunications, and data processing functions called, respectively, the Global Observing System (GOS), the Global Telecommunication System (GTS), and the Global Data Processing System (GDPS). Conceptually, it is convenient to think of the WWW as organized on a three-level basis, namely the global, the regional, and the national levels.

Many of the activities of the WWW – its evolution, its accomplishments, and its future goals – are discussed in the opening section of this plan. There the results of a decade of successful planning and action taken as part of the WWW are emphasized. This section highlights information on current activities and repeats earlier material only where it is necessary for continuity and clarity.

Global Observing System

The Global Observing System consists of two subsystems which provide the meteorological and related environmental observations needed for the WWW and GARP. The first, the space-based satellite subsystem, is composed of polar-orbiting satellites and those in geostationary orbit. The second subsystem, the surface-based system, is composed of the basic synoptic surface and upper air networks, other stations on land and sea, and aircraft meteorological observations.

Rapid technological changes and exploding requirements for data from applied programs, particularly environmental monitoring, have led to important additions being included in the 1976-1979 Plan. Geostationary and polar-orbiting meteorological satellites will play an ever increasing role. Automatic weather stations and buoys will become important sources of environmental information from data-sparse areas. Solid-state radars have already proven their value in the tropics to obtain upper wind data. The implementation of geophysical monitoring stations and the expansion of related observing programs have taken on an increased importance and are receiving special attention.

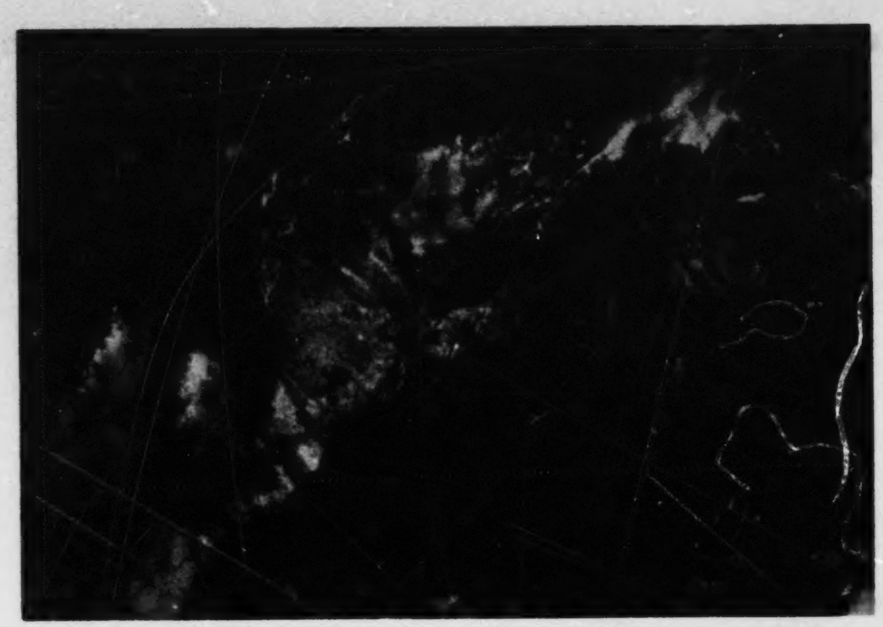
Satellite Observation

Each polar-orbiting satellite is capable of providing two global sets of observations daily of cloud cover, vertical temperature and humidity profiles, sea-surface and land temperatures, and snow and ice cover.

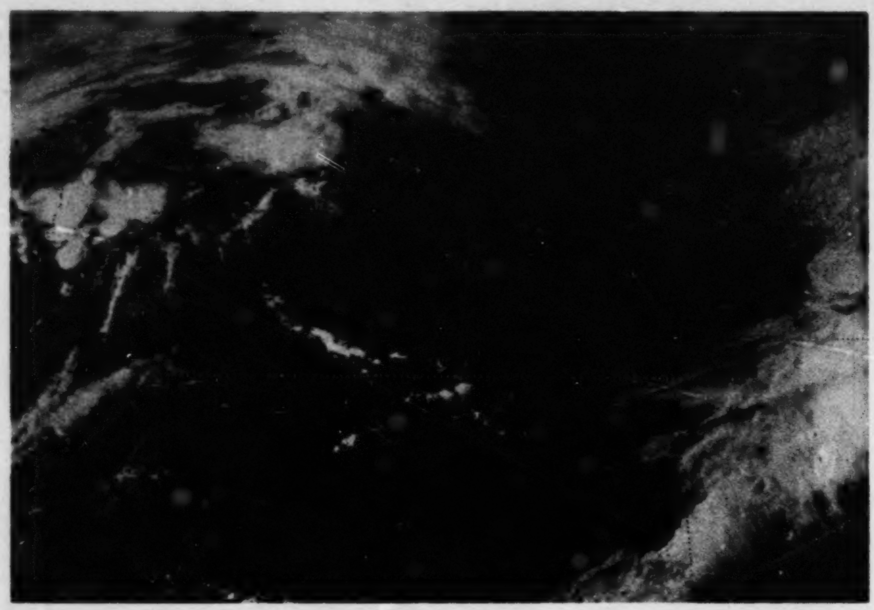
Many of these data are inputs to numerical models for global analysis and prediction of weather systems. Data are received at Wallops Island, Virginia; Gilmore Creek, Alaska; and San Francisco, California; and then distributed by facsimile to National Weather Service forecast offices. Both the United States and the U.S.S.R. operate polar-orbiting satellites as part of the WWW.

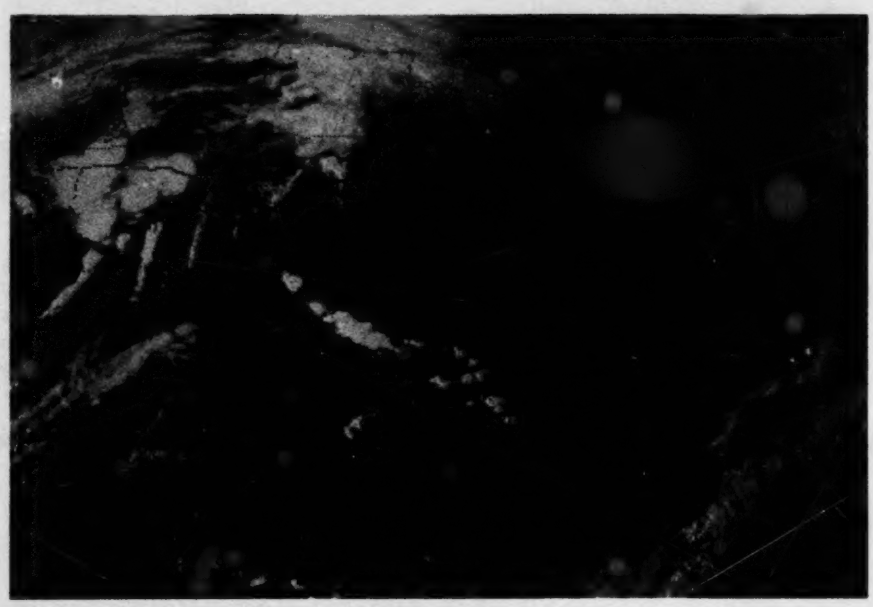
The United States initiated the first stage of an operational geostationary satellite system with the successful launchings of the Synchronous Meteorological Satellites, SMS 1 on 17 May 1974, SMS 2 on 6 February 1975, and the Geostationary Operational Environmental Satellite (GOES-1) on 16 October 1975. The SMS 1 has been put on a reserve status after the partial failure of some systems. Launchings of three additional geostationary satellites are planned by the European Space Agency (ESA) and the Japanese and U.S.S.R. Governments before the end of 1978. Geostationary satellites monitor solar radiation, provide nearly continuous imaging of cloud cover and wind fields derived from cloud motions, and are relay points for data collection and distribution. Currently 55 National Weather Service forecast offices and forecast centers receive SMS and GOES data.

While the United States now relies heavily on the GOES, much of the world will continue to rely on polar-orbiting satellites for local satellite imagery until ESA, the U.S.S.R., and Japan launch their geostationary satellites. Local readout of cloud image data is still available from U.S. polar-orbiting satellites through the Automatic Picture Transmission (APT) service to all meteorological services that have radio receiving equipment capable of satellite signal reception. This system provides instant weather information, both day and night, over thousands of square miles in the vicinity of the local readout stations.

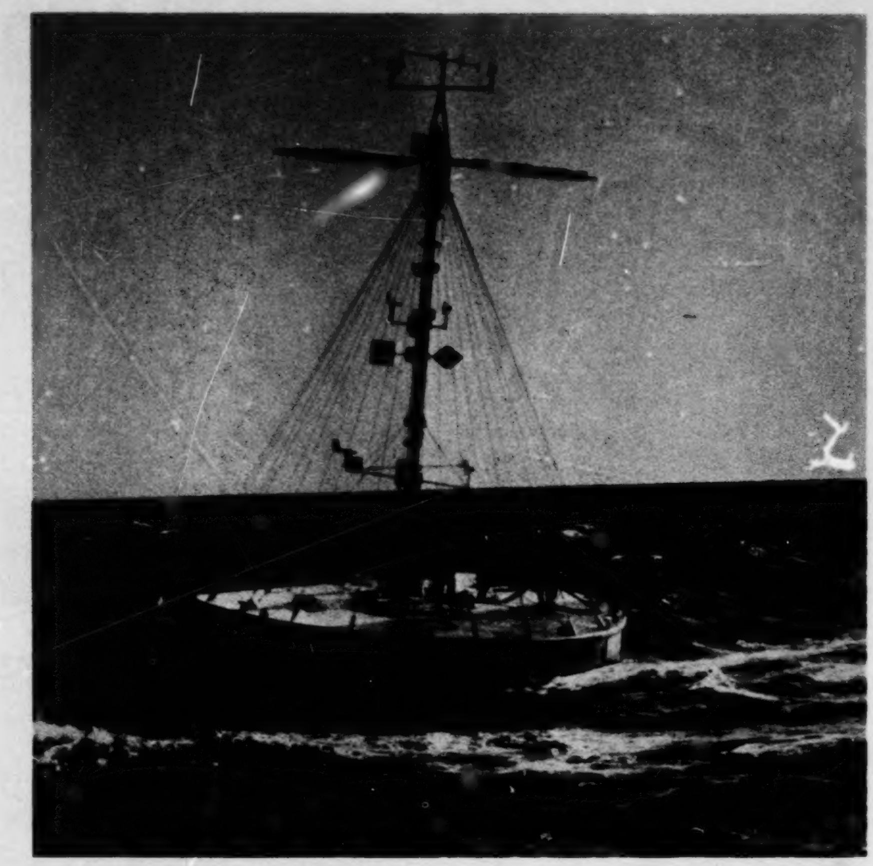


Sequence of infrared, Very High Resolution Radiometer images from NOAA-4 satellite on February 3 and 23, 1976 (top to bottom) showing the ice break-up on Lake Erie. Sequences like these have greatly aided ice surveys and shipping advisories to the Great Lakes, St. Lawrence Seaway and North Atlantic.





This series of GOES images were taken on June 12, 1976 at 1530 EDT (top) and 1630 EDT. The line of thunderstorms from central Virginia to southern Lake Michigan develops rapidly and is indicative of the detailed systems that can be followed in GOES imagery. Note the streamers of clouds pointing to the east and southeast from the cloudline over Missouri. These streamers follow the upper level wind flow. Wind speed and direction can be obtained by tracking individual cloud elements.

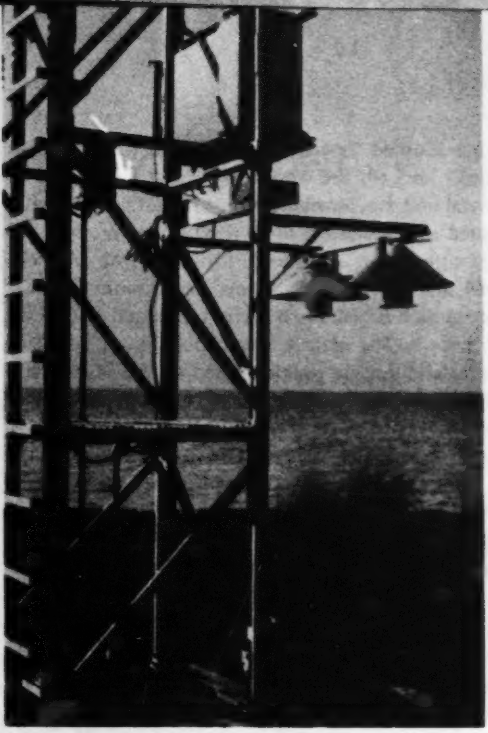


The operational environmental buoy system evolved through cooperative efforts of the Departments of Transportation and Commerce. Large navigational buoys developed for the Coast Guard were expanded in capability to become prototypes for the environmental buoy system. An operational prototype buoy similar to XERB-1 shown here is located 400 kilometers off the Oregon coast and five more will be added this fiscal year from Alaska to California.

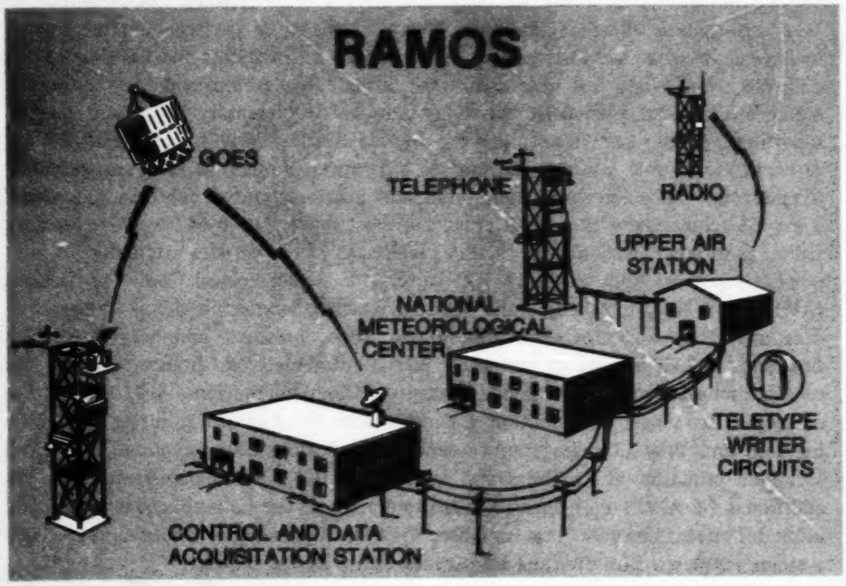
Surface-Based Observations

Monitoring the global environment from the storm scale through the planetary scale requires a variety of surface-based observations. During the early part of the 1976-1979 period, more than 3,500 surface synoptic stations, about 700 upper air sounding stations, and 100 optical wind-finding sites will constitute the primary sources of meteorological data needed by WMO Members for operational and research purposes. These stations comprise the Regional Basic Synoptic Networks in each WMO Region.

Over 6,000 mobile ships from many nations participate in the WMO Voluntary Observing Ship program and furnish nearly all the surface observations from ocean areas. Upper air observations over the oceans are obtained from Ocean Station Vessels and islands in the major oceans.



Portion of RAMOS installation on the Chesapeake, Tilghman Island, Maryland. The conical shields house temperature and humidity sensors and the electronics are located in the rectangular box. Stations like these are an essential part of WWW programs to obtain long term data from isolated locations.


RAMOS
GOES
TELEPHONE
RADIO
UPPER AIR STATION
NATIONAL METEOROLOGICAL CENTER
TELETYPE WRITER CIRCUITS
CONTROL AND DATA ACQUISITATION STATION

The Remote Automatic Meteorological Observing Station (RAMOS) system includes sensors and electronics at an unmanned site which transmit data to forecast and processing centers via geostationary satellites, VHF radio or telephone.

Buoys. The United States has moored nine buoys off the east coast, in the Gulf of Mexico, in the Gulf of Alaska, and off the west coast of the United States. Eight of these buoys are experimental and are providing data to coastal stations for further dissemination. The ninth, called Environmental Buoy (EB) 16 and moored 385 kilometers off the Oregon-California coast, is an operational prototype. Air temperature, sea-level pressure, wind speed and direction, sea-water temperature, surface salinity, and subsurface data are relayed each 6 hours to a shore station and from there to the Global Telecommunication System. The eight experimental buoys are being refitted with the advanced electronics and sensing packages used on EB 16 to make them operational. Five of these eight will be on station by fall 1976 along the shipping route from Alaska southward along the West Coast. France, Japan, the Netherlands, Norway, Portugal, and the United Kingdom also operate fixed buoy stations. The United Kingdom, Norway, Canada, South Africa, France, and Australia have deployed drifting buoys in conjunction with the Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE) of NIMBUS 6.

Aircraft. Aircraft reports constitute a valuable source of upper air information especially over the oceans and sparsely inhabited areas. Weather reports from commercial aircraft, made and reported internationally in accordance with procedures established by the International Civil Aviation Organization (ICAO) for enroute flight advisory service, are also used for providing current flight weather information.

In support of tropical cyclone forecasting, the Department of Defense conducts reconnaissance flights over Northern Hemisphere waters where tropical storms exist or are suspected. Weather observations are collected at flight level, and instruments are dropped from the aircraft to make measurements from flight altitude to the surface of the earth. The Department of Commerce, which performs tropical storm reconnaissance primarily in support of research and development programs, provides backup for hurricane reconnaissance aircraft in the Atlantic and Caribbean.

Automatic Weather Stations. The need for more surface data to support hydrologic, marine, aviation, and agricultural forecast programs and for climate and pollution monitoring has intensified the effort to develop and use automatic meteorological and hydrologic observing stations. Rudimentary automatic stations reporting by radio were used along the Florida Keys as early as the late 1940s and early 1950s to give advance warning of hurricanes. Present devices use the latest advances in solid-state electronics, mini- and micro-computers for data processing; some use solar cells to charge batteries; and most report data over telephone lines, by radio, or through geostationary satellites while the rest store data internally for later manual retrieval. Approximately 100 Automatic Meteorological Observing Stations (AMOS) have been installed by the National Weather Service, providing a basic set of data including air temperature, dew point, wind, pressure, and rainfall amount. Locations include remote coastal sites such as automated light houses, airports, and remote mountain passes. Automatic Hydrologic Observing Stations (AHOS) have been developed to report precipitation and river flow for hydrologic forecasting. Two hundred and fifty of these stations report observations over telephone lines from locations primarily along rivers and streams of the Appalachian mountains. An additional 44 AHOS sites, located in isolated areas of the Columbia River Basin and around Denver, Colorado, use satellites for data transmission. About 2,500 AHOS systems are planned for eventual use over the entire United States.

While most of the automatic stations support national programs primarily, others provide data exchanged bilaterally or internationally over the GTS as part of the WWW. The most important facet for the WWW, however, is that they all provide data needed to establish a baseline for worldwide geophysical monitoring and climate studies. In the next few years automatic stations will be considered and implemented as necessary for regional programs in support of severe storm forecasting.

■ Global Baseline and Regional Monitoring

The aims of both the United Nations Environment Program (UNEP) and the World Weather Program are to extend and improve the measurements of the atmospheric constituents to permit an assessment of the global impact of man-made and natural constituents on climate. Global monitoring consists of both baseline and regional stations.

Baseline Monitoring. The baseline stations are located in remote areas with long air trajectories passing over uniform surfaces to minimize both natural and man-made pollutants. The U.S. baseline program, a part of the WMO network, is conducted at four observatories: Mauna Loa; American Samoa; Barrow, Alaska; and at the U.S. South Pole Station. The measurements at baseline stations are comprehensive and include the principal trace constituents important for climate studies: Carbon dioxide; ozone; and fluorocarbons.

Mauna Loa is the oldest of the four observatories and has the largest number of measurement programs. It is also the highest observatory at 3400 meters (11,150 feet) and samples tropospheric background air, unaffected by island sources, about half of each day. The measurements continue at Mauna Loa Observatory, unaffected by the U.S. Geological Survey's prediction of a major eruption on the volcano's northeast flank during the next 27 months. Emergency procedures have been established in the event of a fissure near the observatory. An enhanced precipitation chemistry program will be started in FY 1977.

The observatory at American Samoa was completed in 1975 and the full-scale measurement program began in early 1976. The University of Rhode Island is continuing a two-year cooperative program at the observatory site.

At Barrow, Alaska, a full-scale program continues at the baseline observatory a few kilometers northeast of the Naval Arctic Research Laboratory. The addition of a LIDAR program is planned in FY 1977. An automated data recording system and nitrogen dioxide sampling system was installed in FY 1976.

At the U.S. South Pole Station, the baseline observatory (a temporary shelter made of packing boxes) which was installed under the snow in early 1975 is now covered to the extent that the structure is hazardous and a new facility is required. This needed structure is being considered by the National Science Foundation (NSF) for installation during the austral summer of 1976-1977. A complete measurement program is continuing at the South Pole observatory.

Regional Monitoring. Regional stations in the United States concentrate on measurements of man-made atmospheric constituents originating within national boundaries of the contiguous United States. The measurements at these stations may be useful in documenting the levels of atmospheric constituents crossing national boundaries for application to future problems in international law, as well as scientific applications.

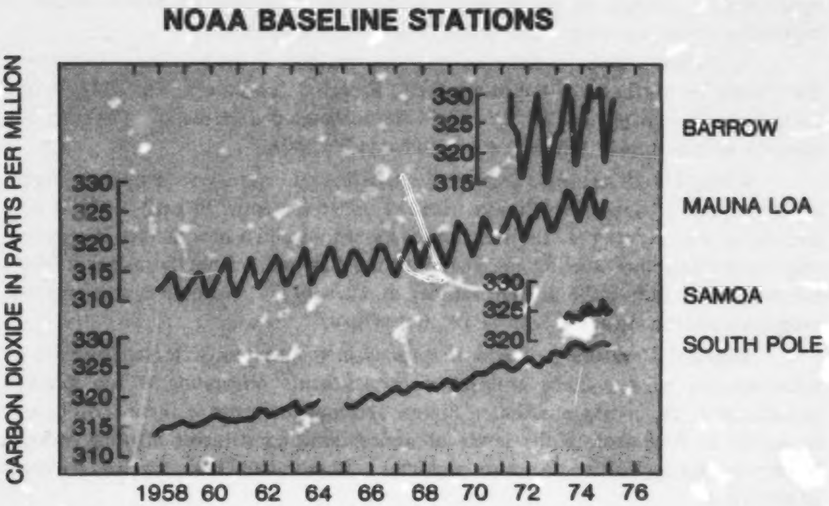
Some U.S. regional stations measure atmospheric turbidity and collect precipitation for chemical analysis. The turbidity measurements allow monitoring of a potential increase in aerosols over the United States, and the analysis of precipitation samples provides information on the acidity of rainfall, which is increasing over the eastern United States.

Other U.S. regional stations measure the total amount of ozone in the atmosphere above the station. These are part of a WMO global ozone network. An expansion in the U.S. regional network is planned in FY 1977 with the addition of a station in the southwestern United States. This will be the first total ozone station west of the Rocky Mountains, which will assist in interpreting long-term ozone trends over the United States.

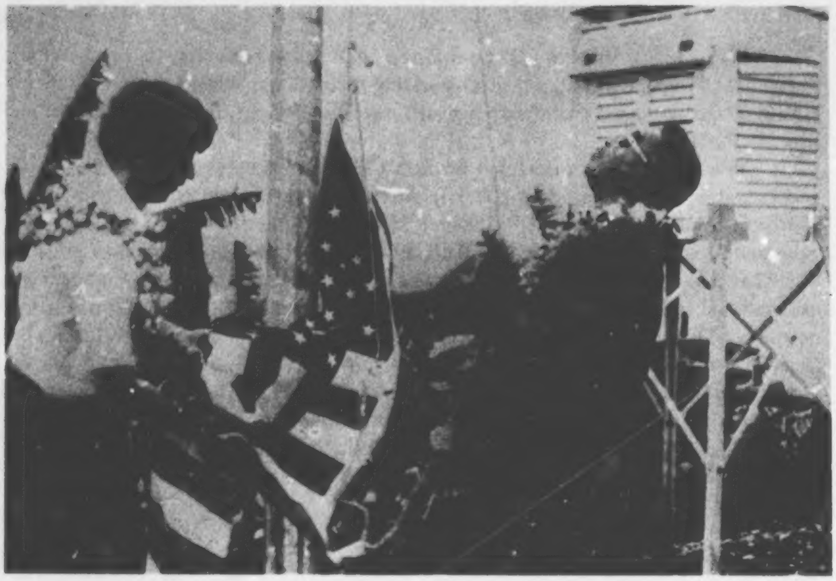
The Energy Research and Development Administration (ERDA) operates a network of 125 land stations to measure on a monthly basis the fallout rate of important radionuclides. Data are used to study the global fallout rate and to assess the fallout inventory. Weekly surface air samples are collected at about 20 stations at latitudes ranging from 77°N to 90°S to provide data on the latitudinal distribution of radionuclide debris.

Deposition of a number of stable trace metals is being studied in New York and San Francisco by ERDA. These studies were extended by installing instruments at NOAA's baseline station at Mauna Loa to investigate baseline levels of various pollutants. A wide spectrum of radionuclides and stable elements will also be measured on a continuous basis at the remotely located air monitoring station at Quillayute, Washington. Correlation analyses of stable, radioactive, and gaseous pollutants and their effect on meteorological conditions are being carried out.

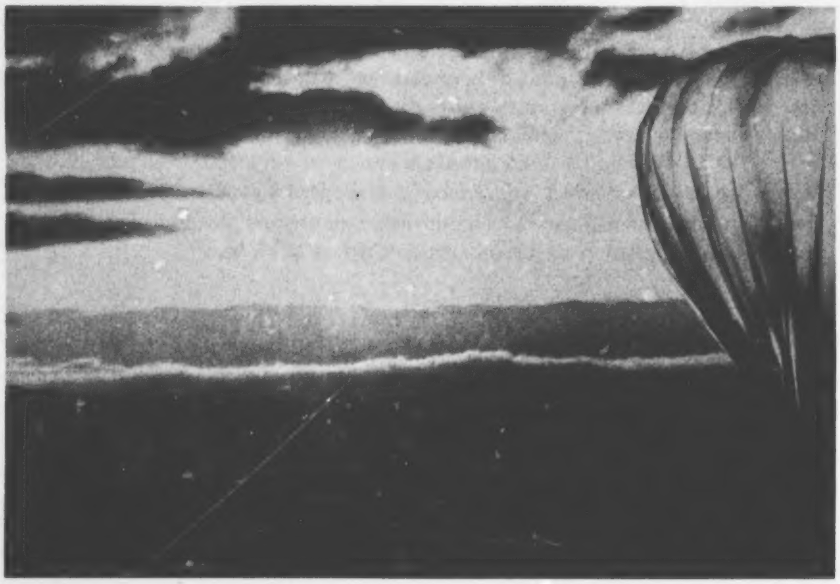
Internationally, WMO has assigned technical responsibility for developing and improving monitoring instrumentation and observational quality to its permanent Commission for Instruments and Methods of Observation (CIMO). WMO recently sponsored two instrument intercomparison sessions for equipment designed to measure sulfur dioxide and the oxides of nitrogen. These meetings were held respectively in Germany and France with eight countries participating in each session.



Trends in atmospheric CO_2 concentration since 1958 at Mauna Loa and South Pole baseline observations, and in recent years at Barrow and American Samoa. Annual change is largest in the northern hemisphere, and an exponential increase is apparent in both hemispheres.



Flag raising ceremony at the dedication of the new U.S. baseline observatory at American Samoa, November 27, 1975. Chief Iuli Togi, from whom NOAA has leased land for the observatory and a NOAA employee are shown.



Preparation of stratospheric balloon and instrument package as part of a routine sampling program to monitor the chemical composition of the upper atmosphere. Ozone and Fluorocarbons are two of the gasses monitored.

Studies of Pollutants

The Department of Transportation has completed its Climatic Impact Assessment Program (CIAP) aimed at assessing the environmental and meteorological effects of the projected worldwide high-altitude aircraft fleet, including subsonic and supersonic vehicles.

New scientific data obtained through CIAP have been used to provide a better understanding of the cause-and-effect relationships between aircraft effluents in the stratosphere and environmental changes. Serious uncertainties still exist, but their magnitude has been reduced substantially so that useful conclusions are now possible. The CIAP report concluded that there was an immediate need to develop national and international regulations to ensure that future increases in high-altitude air traffic will not be accompanied by degradation in environmental quality. To fulfill this need, the Department of Transportation initiated its High Altitude Pollution Program under the direction of the Federal Aviation Administration (FAA). The overall goal of this program is to provide data and analyses needed for appropriate increases in aviation safety, efficiency, and economy to ensure that aircraft emissions during high-altitude cruise operations will not result in adverse environmental effects.

Global Data Processing System

The Global Data Processing System of the international WWW Plan is designed to make available to the meteorological services of the world processed data and products required for preparing forecasts and warnings and for climatological and research purposes. Data are available on a real-time and a non-real-time basis. Adjustments were made in the WWW Plan for 1976-1979 as a result of new developments, including more efficient and sophisticated processing techniques, the availability of more powerful computers, better coordination of the real-time and delayed functions of the processing centers, and emphasis on the four-dimensional data assimilation techniques, particularly vertical sounding data from satellites, to be used in numerical weather prediction.

The GDPS consists of an integrated system of World, Regional, and National Meteorological Centers which utilize modern high-speed computers and data-handling equipment. This international cooperation makes routing and processing large amounts of global data possible with a minimum duplication of effort.

World Meteorological Centers

Three World Meteorological Centers (WMC) are operated in accordance with the international WWW Plan – at Melbourne, Australia (with limited capability), Moscow, U.S.S.R., and Washington, D.C. They process data from the GOS and transmit meteorological analyses and forecasts on a global scale to Member nations of WMO through the GTS.

In the United States the WMC consists of three components: the National Meteorological Center at Camp Springs, Maryland; the National Climatic Center at Asheville, North Carolina; and part of the National Environmental Satellite Service at Suitland, Maryland. Historically, numerical models have used data from fixed or synoptic times; however, with the technological changes brought about by satellite observations, meteorological data are now available on a nearly continuous basis. An analysis scheme now used routinely assimilates into the data base observations taken at any time. A new, fourth-generation computer was an important advance at the WMC which made such data assimilation possible. The new computer is also used to process both day and night images from GOES and to run complex, multi-layered hemispheric and global models. Hemispheric forecasts are made twice a day – one forecast is run out to 4 days and the other to 2 days. The global model is run once a day to 24 hours and is being tested for use on an operational basis. With this and future models now being developed, Washington WMC will be able to meet its present global and hemispheric responsibilities under the WWW.

■ Regional Meteorological Centers

There are 23 Regional Meteorological Centers (RMC) worldwide with limited meteorological analysis, processing, and forecasting capabilities. The United States operates an RMC at Miami which provides regional analyses and predictions for the Caribbean, Central America, Northern South America, and adjacent tropical ocean areas. It is operated in conjunction with the Regional Center for Tropical Meteorology in support of the U.S. hurricane forecasting office. The Center has developed a series of statistical hurricane prediction models aimed at increasing the capability of the Center to more accurately predict landfall and reduce the 24-hour forecast position error. The WMC in Washington has developed a multi-level, fine-mesh hurricane model for operational use at Miami. Products from this model were tested at Miami during the 1975 hurricane season and will be implemented operationally for the 1976 season. In addition to hurricane and tropical storm advisories, the RMC, Miami, provides marine and aviation weather forecasting services to foreign countries in its area of responsibility.

■ National Meteorological Centers

The National Meteorological Centers (NMC) are designated under the international WWW Plan to satisfy the data processing needs on the national level, assisted as required by the output products of WMCs and RMCs. As on the global and regional levels, the NMCs have both real-time and non-real-time functions. At the national level many of the NMCs provide direct support to the users of meteorological services.

In recent years hydrologic forecasting has taken a new impetus as a function supported by NMCs. As an example of the support being provided, generalized models based on physical hydrologic processes have been developed, tested, and integrated to form the National Weather Service River Forecast System (NWSRFS). This system is now being implemented throughout the National Weather Service. The initial version of NWSRFS was first used at the Lower Mississippi River Forecast Center in 1971. Since then, the model has been tested on portions of the Mississippi, Columbia, and Ohio Rivers and is being used operationally this year on about 640 kilometers of river in the vicinity of the confluence of the Ohio and Mississippi Rivers. About 2 years ago research was initiated to develop mathematical models which could incorporate the effects of flood plains, bank seepage, and sediment transport on the unsteady flows of alluvial rivers. In the coming year these newly developed mathematical models will be implemented at U.S. river forecast centers and evaluated under operational conditions.

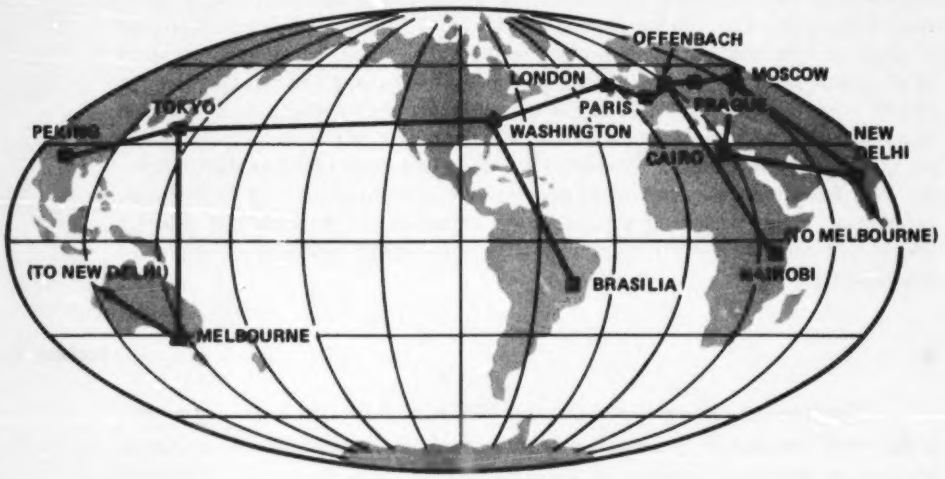
Global Telecommunication System

The Global Telecommunication System (GTS) consists of telecommunication facilities and arrangements necessary for the rapid collection and distribution of basic observational data and processed information. It is organized on a three-level basis:

The Main Trunk Circuit (MTC) and its branches
The Regional Telecommunication Networks
The National Telecommunication Networks

The GTS plan for 1976-1979 includes increased use of computer-to-computer techniques, high-speed data exchange, and the introduction of coded digital facsimile techniques on the MTC. These techniques will permit increased global exchange of satellite data and computer-derived products.

MAIN TRUNK-GLOBAL TELECOMMUNICATIONS SYSTEM



▲ WORLD METEOROLOGICAL CENTER

■ REGIONAL TELECOMMUNICATIONS HUB

The Main Trunk of the Global Telecommunications System and the associated regional hubs connecting the three World Meteorological Centers.

Main Trunk Circuit

The Main Trunk Circuit (MTC) is a high-capacity telecommunications link interconnecting all WMO regions through three World Meteorological Centers and eight Regional Telecommunication Hubs (RTH). Three additional RTHs are situated on branches of the Main Trunk Circuit, one of which was added recently at Peking. The Global Telecommunication System has been designed to handle the expected traffic for the WWW. It is anticipated that the additional traffic generated during the First GARP Global Experiment (FGGE), in particular the data desired for use in real-time, will be accommodated on the GTS as will real-time data needed by EARTHWATCH and IGOSS. Four critical parts of the MTC have a capacity of 2400 bits per second and are capable of handling large amounts of data. Because of the very large amount of data expected to be available from satellites, demands of other UN programs, and stringent time limits set for the transmission of data on the MTC, even higher data signalling rates (e.g., 4800 bits per second) are needed. Further development and improvement of the GTS to provide these higher transmission rates are tasks to be undertaken during the period 1976-1979.

■ Regional Telecommunications Networks

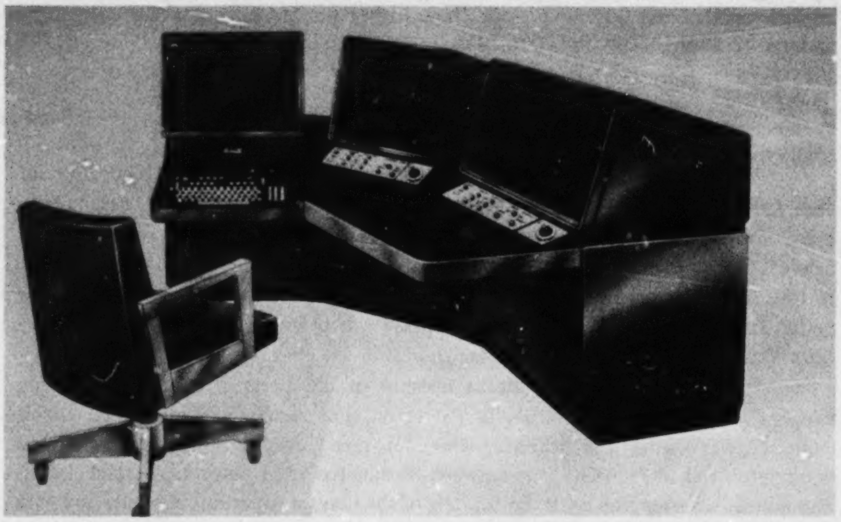
Regional telecommunication networks provide for the rapid collection of observational data at the Regional Telecommunications Hubs (RTH), particularly those that connect regional circuits with the MTC. The regional telecommunication networks also provide for the distribution of observations and processed information to NMCs and thus insure that all Members of WMO receive the data they require. The national telecommunication networks provide the means for collecting and subsequently distributing observational data.

The United States operates a number of international regional circuits in cooperation with other countries in its region. For example, a high-speed circuit connects Washington and Toronto, while low-speed circuits are installed between Washington and Mexico City, and between Washington and Nassau. Low-speed circuits also connect Washington with the capitals of the Central American republics and with many of the islands in the Antilles. The United States also operates three radioteletypewriter broadcasts and one radiofacsimile broadcast within the region.

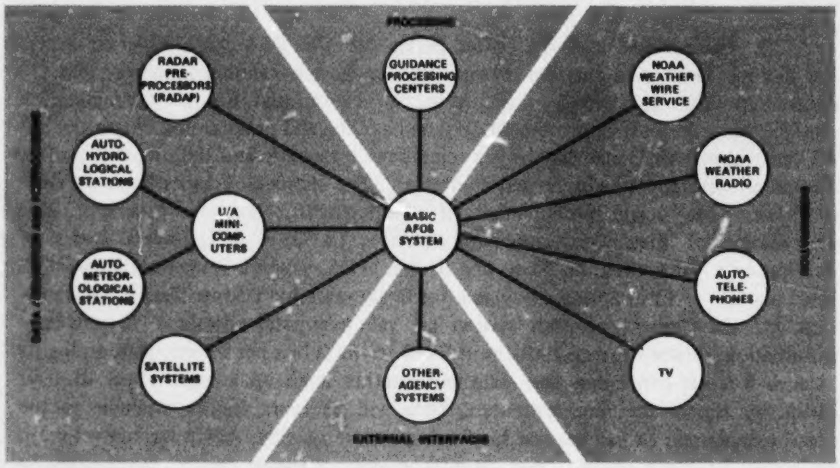
■ National Telecommunications Networks

At the national level the United States has initiated a major effort to change the way meteorological data are (1) entered into the telecommunications system, (2) distributed nationally, and (3) displayed to the meteorologist. For the weather station meteorologist the only improvements in data handling and presentation during the last 40 years have been somewhat higher teletypewriter speeds and the use of facsimile. The present system is being revised completely. The National Weather Service (NWS) of NOAA has begun procurement of equipment for its new program called Automation of Field Operations and Services (AFOS). After several years of development and evaluation, phase one of the AFOS system is being installed at NWS Headquarters in Silver Spring, Maryland, for final evaluation prior to field implementation. At the "heart" of each station are mini-computers designed to exchange information between forecast offices at 2400 to 4800 bits per second. Meteorologists at each forecast office can view data and weather maps on television-type displays driven by the on-site mini-computers. Data will be more readily available to the meteorologist and he can prepare his forecasts more quickly. AFOS will allow him to be better informed and to keep up with rapidly changing events. In addition to changes at the forecast office and in the telecommunications network, AFOS will allow the direct input of digital data from observing systems such as automatic weather stations, semi-automated upper air sites and storm detection radars equipped with mini-computers.

AFOS was demonstrated to the 130 scientists and observational specialists who attended the WMO-sponsored Technical Conference on Automated Meteorological Systems in Washington, D.C., during February 1975. People from several countries showed great interest, and Canada has begun a complementary effort to interface its observational and communications networks with the AFOS system.



Artists conception of the operational AFOS console for hydrologists or aviation forecasters. Experimental AFOS systems are under final evaluation prior to field installation which is scheduled to begin in CY1977.



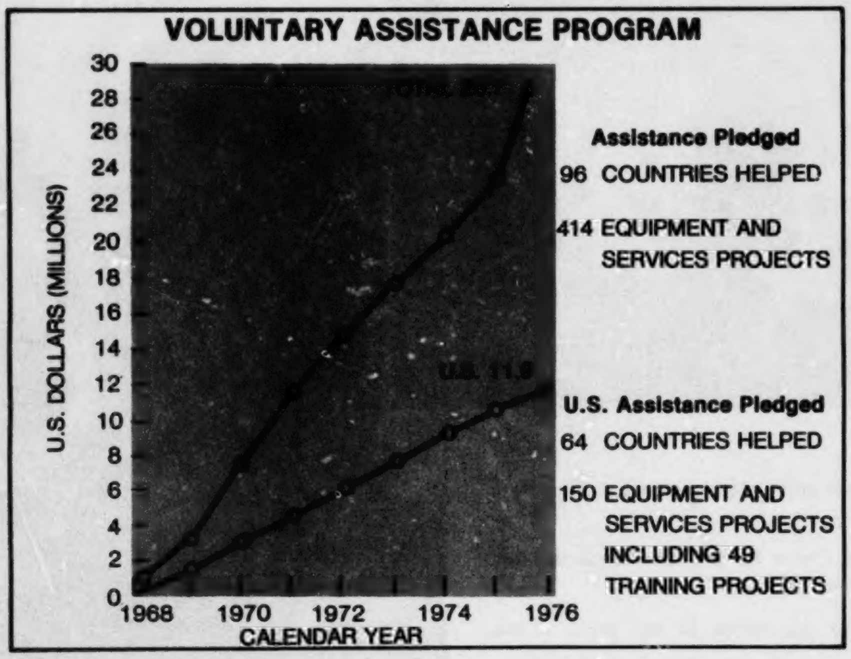
Automation of Field Operations and Services (AFOS) will greatly improve the speed with which meteorological data can be collected, processed and used by the forecaster. Mini-computers will also facilitate the dissemination of warnings and forecasts to the public.

Voluntary Assistance Program

The implementation and development of, and benefits to be realized from the WWW are dependent upon the participation of all the meteorological services of the world. Some developing countries do not have the resources or the technical and scientific knowledge to participate freely in the World Weather Program. Technical and financial assistance provided to these countries results in both an improvement of their meteorological and hydrologic programs and a more vigorous international effort. Assistance may be provided in part by:

The United Nations Development Program
Bilateral or multi-national agreements
Contributions in financial form or in the form of equipment or services by Members of the WMO. These latter contributions constitute the WMO Voluntary Assistance Program (VAP). The history of VAP is shown in the accompanying figure.

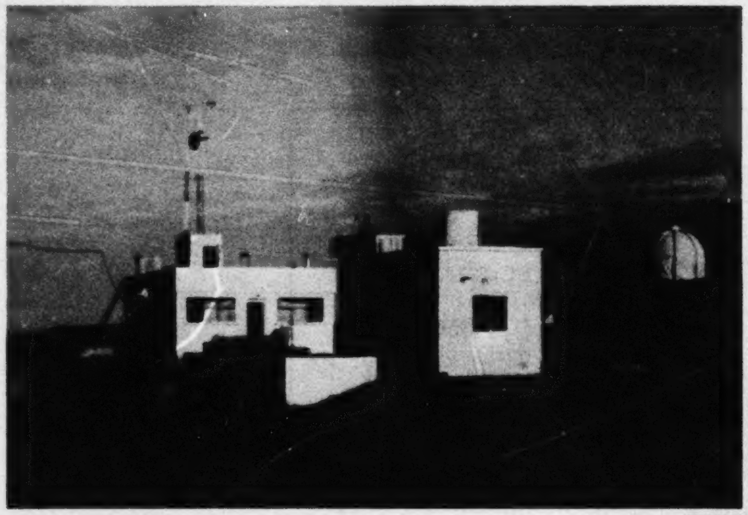
The Voluntary Assistance Program is a major form of assistance in helping developing countries to implement and benefit from the WWW by providing equipment, expert services, and long-term fellowships. The priority for support includes elimination of major deficiencies in the observing functions, in the capabilities of the telecommunications system to move data globally, and in qualified personnel to make use of the meteorological data made available through the WWW. Support



Contributions to the WMO Voluntary Assistance Program by the United States and other nations through 1975.

1.

2.



3.

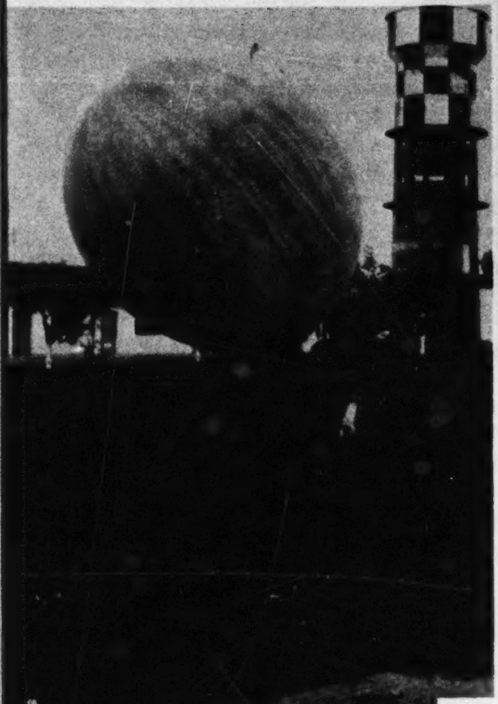
1. Installation of VAP surface observing equipment at Freetown, Sierra Leone, W. Africa - 1972.

2. Meteorological Office and dome for the rawinsonde tracking antenna at Isla Socorro, Mexico - 1976.

3. Tracking antenna prior to installation in the dome at Isla Socorro - 1976.

5.

4.

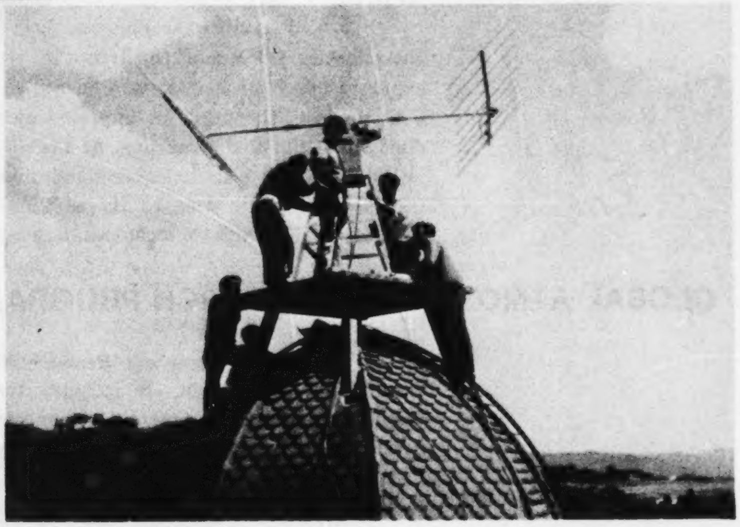


4. Final preparation of rawinsonde balloon and instrument at the VAP station in Asuncion, Paraguay - 1975.

5. Antenna for new, solidstate windfinding radar being tested at the factory in Enterprise, Alabama. These systems are now being provided through VAP.

6. Installation of an Automatic Picture Transmission (APT) antenna in Guatemala - 1972.

6.



through VAP has been provided in Africa, South and Central America, and Asia to improve the availability of upper air data from these locations. Deficiencies still exist in tropical areas and these will be addressed during the 1976-1979 period. As a result of VAP all the RTHs on the MTC and its branches have been implemented. Except for a few facilities the RTHs on the regional meteorological circuits have also been or are in the process of being implemented. Point-to-point and national observational collection networks are expected to be fully supported by the end of 1979.

Due to U. S. VAP support, the RTH in Brasilia has point-to-point circuits to Buenos Aires and Maracay and an upgraded (higher power) circuit to Washington. Maracay will also have circuits to Quito and Bogota, and Buenos Aires will have a circuit to Montevideo. VAP assistance to Peru, Bolivia, and Paraguay will permit upgrading of their capability in the South American Regional Network. Through VAP the national telecommunications networks in Ecuador, Argentina, and Uruguay have added data to the South American and global networks.

The Central American area has been improved also by implementation of national telecommunications networks in Honduras, Nicaragua, and Guatemala. These networks will be expanded to include Panama and British Honduras. The availability of surface and upper air data from Mexico has been increased through a point-to-point circuit from Isla Socorro to Mexico City. VAP projects of additional local benefit are the fascimile projects for Nicaragua and Guatemala.

The United States provides similar support for some African and Asian countries and participates with other WMO Member nations in cooperative support programs for large VAP projects. Examples include telecommunications projects in Kenya, the Philippines, and Thailand and upper air station projects in Brazil, Ghana, and Indonesia. The upper air installation in Ghana is shown in the adjacent figure.

During CY 1975 Members of the WMO contributed $547,000 to the VAP cash fund; the United States contributed $150,000. Also during this period 12 other WMO Members contributed $850,000 in equipment and $800,000 in services to VAP. The United States contributed the equivalent of $1,350,000 in equipment and services during CY 1975. No change in the level of U.S. participation in VAP is expected for CY 1976.

A VAP donors meeting was held in February 1976 to explore ways of improving the WWW so as to advance the goals of FGGE. Critical locations for new or improved upper air stations were identified and priorities were assigned for possible VAP support. The need for improved electronics and technician training was also discussed at the donors meeting. As a result the United States, using VAP funds, has placed a NOAA electronics/communications technician on limited assignment in Central and South America. In addition the United States is making available short-term fellowships for technician training.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM ■

The Global Atmospheric Research Program (GARP) is the research part of the World Weather Program. It includes theoretical, numerical, and observational experiments designed to improve our understanding of the global atmosphere and to develop and test physical-mathematical models. GARP has two major objectives which may be summarized briefly as (1) extending the range, scope, and accuracy of weather forecasts and (2) understanding the physical basis of climate and climatic fluctuations.

Both objectives require the careful investigation of complex physical processes and the mounting of special observational experiments required to formulate and test theories and models. Some processes can be studied through regional experiments. Examples are the GARP Atlantic Tropical Experiment (GATE), which emphasized the role of convective tropical systems on the global circulation; the Air Mass Transformation Experiment (AMTEX), which concentrates on the processes of intensive transformations of air moving from cold land over strongly contrasting warmer water; the Monsoon Experiment (MONEX), which studies the mechanics of the Monsoon circulation; and the Polar Experiment (POLEX), which examines the role of polar regions in global energetics.

The second GARP objective, climate, leads inevitably to consideration of the role of the oceans and the development of coupled ocean-atmosphere models. The following sections present some highlights of current GARP activities.

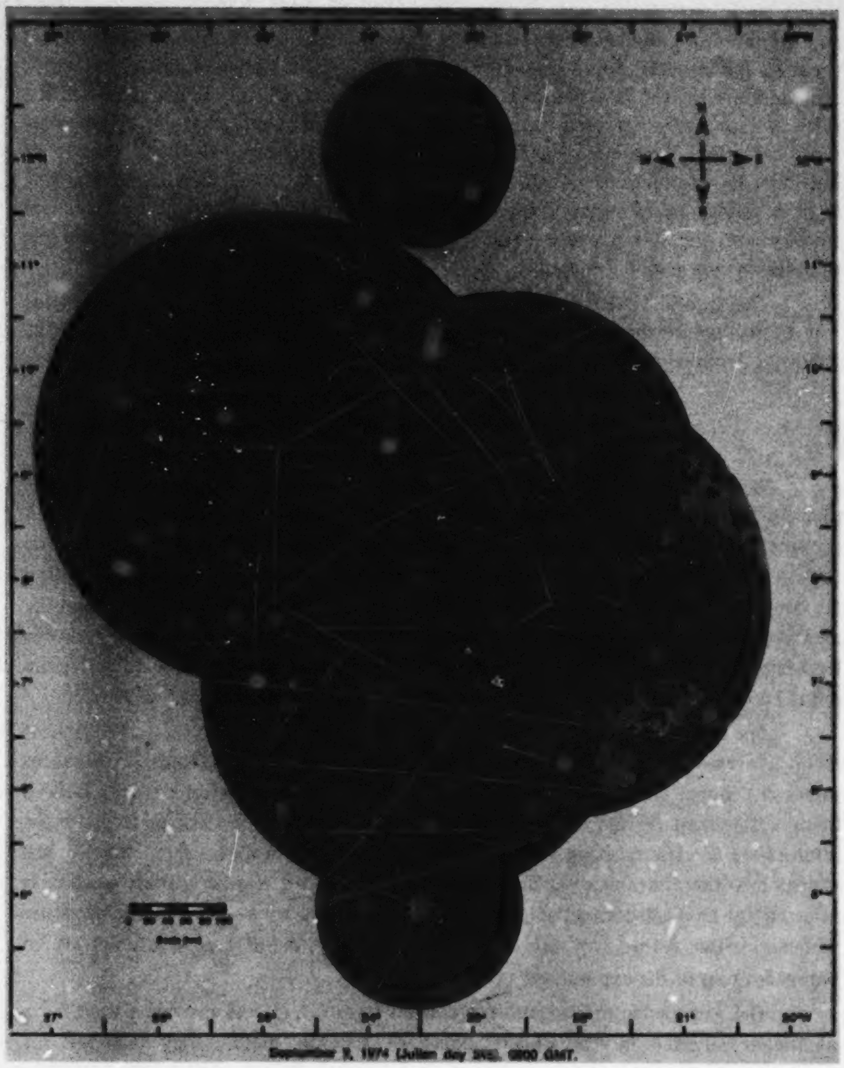
■ GARP Atlantic Tropical Experiment

The GARP Atlantic Tropical Experiment (GATE) conducted its field observation program between 15 June and 30 September 1974. Scientific, technical, and support personnel from 69 nations merged their efforts into a concentrated and coordinated investigation of the behavior of and interactions between the tropical atmosphere and oceans. The main base of field operations was Dakar, Senegal, and the area covered by the experiment stretched over more than one-third of the earth's tropical belt, extending from the Pacific coast of Central America eastward across the entire tropical Atlantic and African continent to the Indian Ocean coast of Africa.

The principal objectives of GATE are to study the structure and evolution of tropical weather systems and to assess the extent to which these tropical disturbances affect the global circulation. It is believed that tropical convective systems, besides being a dominant feature of the weather in the tropics, provide a driving force for the atmosphere by transporting vast quantities of heat and moisture from the tropical oceans into the atmosphere at higher latitudes. Therefore, middle latitude weather is affected by tropical convective activity. These systems are coupled to the processes and circulation features of the oceans; consequently, oceanographic studies are an important part of the experiment.

The knowledge and experience derived from GATE will provide a basis for a significant advance in the understanding of tropical meteorology and for the development of weather forecasting in the tropical belt. The processes under study are also fundamental to initiation, development, and maintenance of intense tropical storms and hurricanes that menace populated areas surrounding the tropical oceans. Improvements in the physical formulation of tropical processes in large-scale mathematical models of the global atmosphere are required to permit significant extensions in the range and quality of forecasts at any location and to gain understanding of climate and climatic change.

All available information indicates that the data collected will be adequate to attain GATE's scientific objectives. Current efforts within the GATE program are directed toward processing and validating the data and fostering a comprehensive research program.



September 9, 1974 (Julian day 252), 0900 GMT.

Example of composite weather radar coverage during GATE. Products like these are being prepared by Subprogram Data Centers as part of the effort to compile data for scientific analysis.

Data Management

The GATE data are being processed according to guidelines documented in the GATE International Data Management Plan and outlined schematically on the adjacent flow chart. Participating nations have been processing and validating the data collected by their respective national systems since the conclusion of field activities. Some specific problems have developed and schedules for some data have slipped beyond the stated deadline of 31 March 1976, but the most critical data sets are being made available in a timely manner.

GATE data are sent by the National Processing Centers (NPC) to the World Data Centers (WDC) in the United States and the Soviet Union immediately upon completion of processing. A GATE Data Catalog prepared by WDC-A in the United States lists the data available. This catalog, which is distributed internationally, is updated at 3-month intervals to ensure that scientists become aware of the addition of newly processed data to the archives.

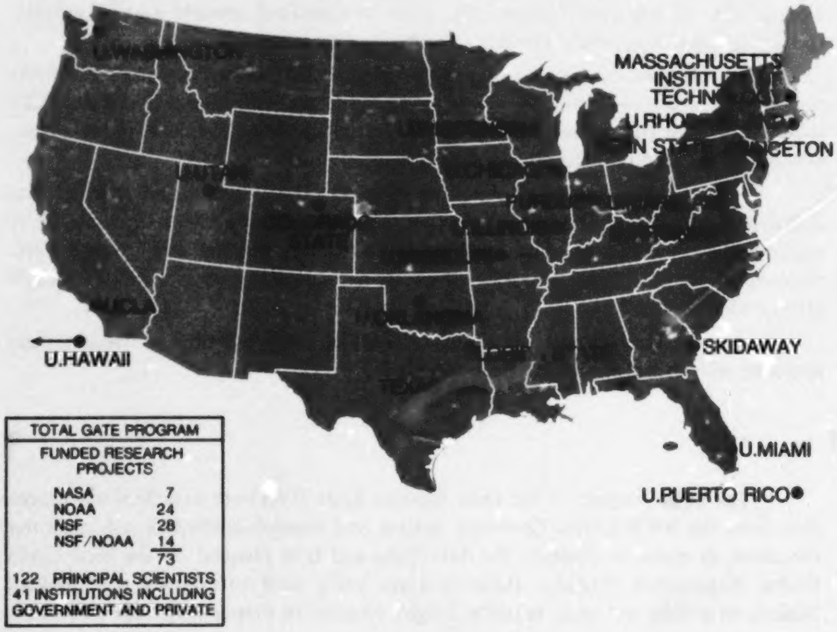
Specialized data-processing activities are also underway at five international Subprogram Data Centers (SDC) located in the Federal Republic of Germany, the Soviet Union, the United States, the United Kingdom, and France. The SDCs are designed to generate data sets specifically tailored for certain major scientific problems. The SDCs are responsible for merging preselected data sets from the various countries, performing intercomparison and validation activities, and producing final data sets tailored for the users needs. An example of a SDC product (shown in the adjacent figure) is a composite of the radar data taken at one instant during GATE by Federal Republic of Germany, U.S.S.R. and U.S. vessels. The SDC products are scheduled to be completed by 31 March 1977.

■

GATE Research Program

The international GATE research program is off to a promising start and is expected to gain momentum as the volume of data available through the WDCs continues to grow. The time devoted to discussion of GATE topics at international

U.S. GATE RESEARCH PROGRAM AT UNIVERSITIES



scientific meetings and conferences has increased within the last year, and scientific papers dealing with GATE topics have begun to appear in the professional literature.

The United States is heavily committed to conducting a successful research program based on the GATE data set. As shown in the accompanying diagram, this research effort is national in scope and reflects a major involvement by both the government and universities. One hundred and twenty-two principal scientists at 41 institutions have been funded to work on specific GATE problems; significant efforts are also underway at several government research institutions.

A major task within the framework of GATE involves the synthesis of the results of these research programs into a comprehensive report dealing with the central objectives of the experiment. Detailed planning for preparing the report is currently underway in the United States. A major seminar will be held during the summer of 1977 to develop the content of the report. Similar international activities will probably take place during 1978 and 1979.

Preliminary Results of GATE

Although major statements regarding the results of GATE will probably have to await the completion of at least the 1977 synthesis activity, some preliminary results from the experiment are already apparent. These include:

–The large-scale atmospheric wave systems that control (and are in turn influenced by) tropical convective systems have been isolated, and studies of their movement and life cycle have begun. The GATE data have provided the first adequate representation of these waves.

–GATE data show that the atmosphere below the cloud layer responds strongly to the vertical circulations associated with convective systems. Ideas of how to develop mathematical descriptions of these processes are emerging. These descriptions or parameterizations are vital if numerical models are to simulate accurately the atmosphere's response to tropical convection.

–Models of the vertical-profile radiative flux divergence calculated from atmospheric soundings have been constructed and tested with special GATE data. The results show that the radiative flux divergence can be modeled for clear air. Models are now being developed for the cloudy atmosphere.

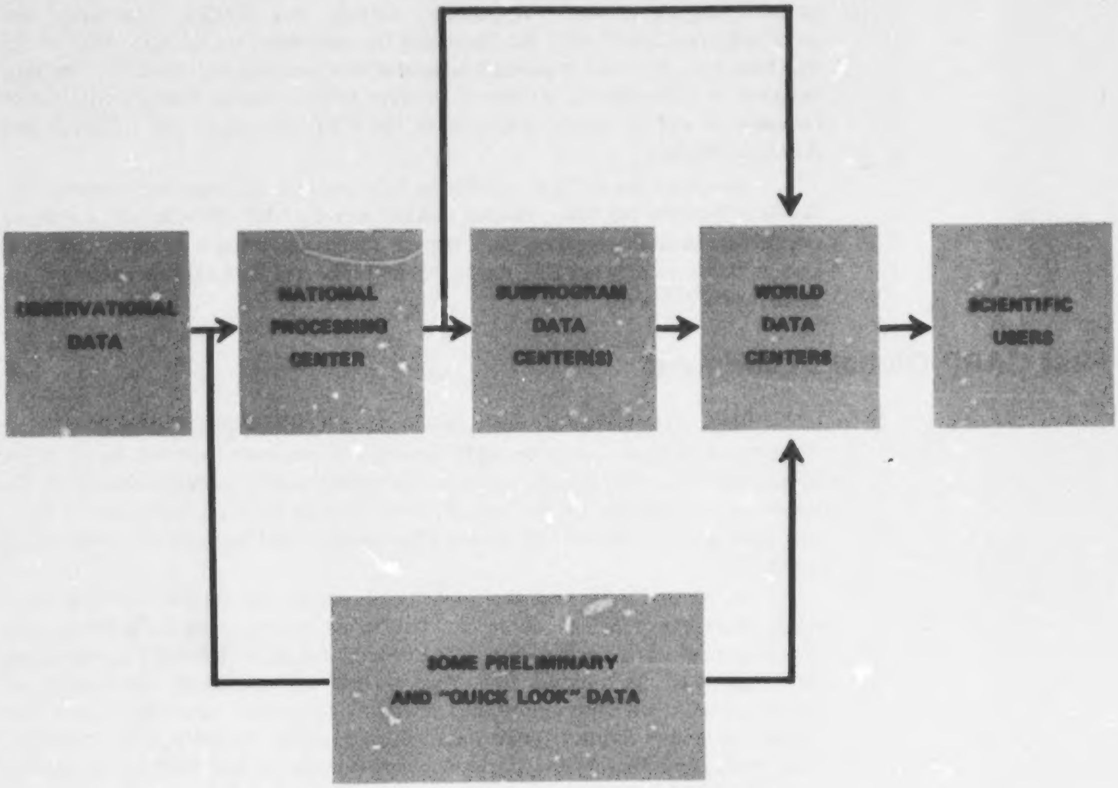
–A large-scale fluctuation in the equatorial ocean undercurrent was discovered during GATE and a discussion has begun of the theoretical models to explain this phenomenon. The relationship of this fluctuation and other oceanic phenomena to the convective state of the tropical atmosphere is a major research effort under GATE.

–Research progress in air-sea interaction, ocean mixed layer dynamics and response, and aerosol studies has been reported.

Data Systems Test

The basic purpose of the Data Systems Tests (DST) are to collect and process data from the WWW Global Observing System and research satellites in a manner that simulates, as much as possible, the data types and flow planned for the First GARP Global Experiment (FGGE). These data are being used to evaluate mathematical models, providing not only valuable insight to assist in preparing for the FGGE but

BASIC GATE DATA FLOW


OBSERVATIONAL DATA
NATIONAL PROCESSING CENTER
SUBPROGRAM DATA CENTER(S)
WORLD DATA CENTERS
SCIENTIFIC USERS
SOME PRELIMINARY AND "QUICK LOOK" DATA

also a means for evaluating and improving current operational systems. NASA directs and manages the DST with the cooperation and participation of NOAA, the National Center for Atmospheric Research (NCAR), the University of Wisconsin, and the University of California at Los Angeles (UCLA). NASA operates a project office for implementation and operational management of the DST. The National Meteorological Center of NOAA collects and merges the data into global sets, which can be used in the analysis and prediction models developed by the various user groups. Results of DST studies are being used to assess the adequacy of the data acquisition, data processing, and data utilization systems essential to FGGE. Sets of global data collected so far have been more complete than any previously collected. These data should prove very useful for weather and climate research in the period before data from the FGGE become available. NASA is providing the data sets to selected scientific investigators for research studies on FGGE-related problems.

One extended period of data collection was conducted from 18 August to 18 October 1975 and another from 5 January to 5 March 1976. In addition to the regular observations from the WWW networks, special data sets were obtained of (1) vertical profiles of temperature from satellite sounders on both operational polar-orbiting satellites and the NIMBUS 6 research satellite, (2) wind vectors derived from cloud motions by the University of Wisconsin and NOAA, (3) wind and temperature from

TWERLE constant level balloons, and (4) observations from specially equipped commercial aircraft. For these last observations, tape recorders on wide-body jets recorded flight-level wind, temperature, altitude, and position. The tapes were processed immediately after the flight and the data sent over the GTS. Most of the data have been processed to produce integrated data sets, and several subsets have been analyzed to determine the extent of coverage to be expected during future GARP experiments and to isolate problems in the WWW procedures for collecting and disseminating data.

Data from the DSTs have yet to be fully analyzed and evaluated. However, the Goddard Institute for Space Studies (NASA) and the NMC (NOAA) are performing satellite temperature-sounding data impact studies on weather analyses and forecasting. Based on previous DST results, these studies will have a significant impact on FGGE and WWW plans.

First GARP Global Experiment

Regional experiments such as GATE, AMTEX, MONEX, and POLEX are designed to improve understanding of atmospheric processes important to the global circulation of the atmosphere; processes that cannot now be modeled adequately. The results of regional experiments and the Data Systems Tests are being applied to the formulation of the First GARP Global Experiment (FGGE) scheduled for the period 1977-1979.

Better and more complete global observations are required for two broad applications. First, they are needed to establish the starting point for global weather forecasts made using existing physical-mathematical models of the global atmosphere. The quality of the forecasts from these models reflects directly the quality and completeness of the observations used to specify the present atmospheric state from which the models forecast future states. Second, global observations are needed to test, verify, and improve the performance of existing models. Only by comparison with actual observations can critical improvements be achieved.

The major objectives of the FGGE are:

–To better understand atmospheric motion for the development and evaluation of more realistic models used in extended-range forecasting and studies of the general circulation and climate;

–To assess the ultimate limit of predicability of weather systems of various sizes and time scales;

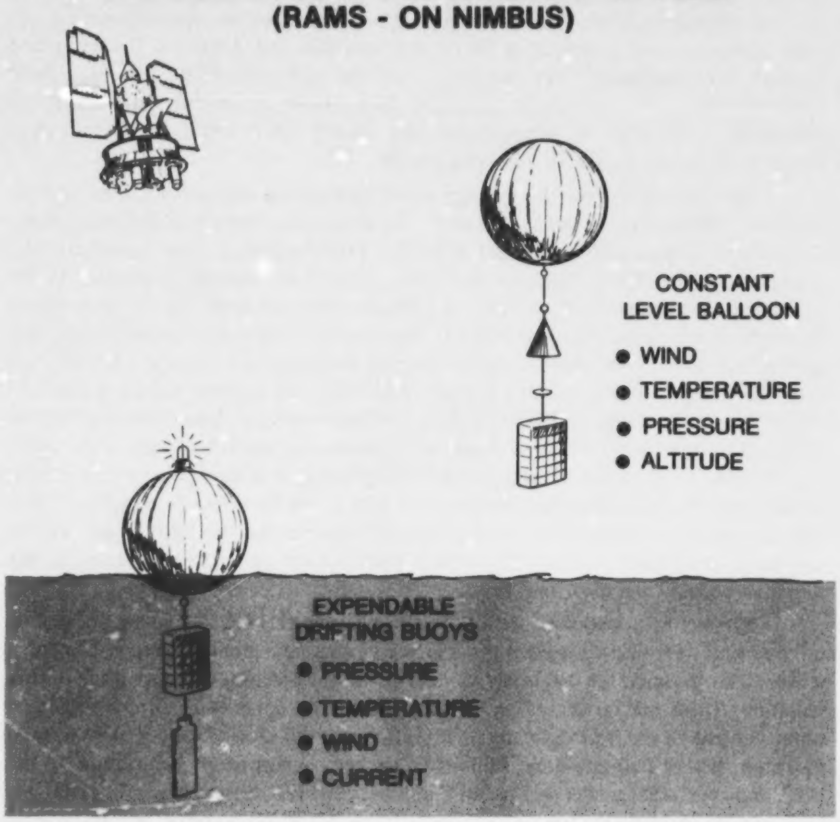
–To develop more powerful methods for assimilating multi-source meteorological observations, particularly for using nonsynchronous satellite data to determine the initial state of the atmosphere for predicting large-scale motions; and

–To design an optimum composite global observing system for the operational WWW.

These general objectives are being translated into concrete research objectives through a series of FGGE workshops in the United States. The results of these workshops will form the basis of an integrated and coordinated research program aimed at using the special skills of three unique sources:

–Individual research at universities
–Large numerical modeling groups
–Government agencies.

TROPICAL WIND ENERGY CONVERSION REFERENCE LEVEL EXPERIMENT (TWERLE)
RANDOM ACCESS MEASUREMENT SYSTEM (RAMS - ON NIMBUS)



■

Observing Systems

The FGGE observing system may be subdivided into three components; (1) those associated with the WWW, (2) special atmospheric observing systems, and (3) systems associated with special oceanographic and atmospheric regional experiments. Through its observing, processing, and telecommunications systems the WWW will provide the basic data for FGGE throughout the entire observational period. The availability of a satellite system consisting of a two polar-orbiting satellite system and five geostationary satellites spaced around the globe is one of the most critical factors in the conduct of FGGE. The next generation polar-orbiting satellite system (TIROS-N) will provide more accurate soundings and a capability to locate and collect data from mobile platforms. Earth-based observations from WWW networks will be indispensable and will include new stations implemented in accordance with the international World Weather Watch Plan for 1976-1979. Special importance is attached to twice-daily radiosonde/radiowind observations and the collection of data from commercial aircraft and ships.

Plans for developing an automated aircraft reporting system, a new element of the WWW, are progressing on schedule. NASA and NOAA are cooperating in the development and test of the system called Automatic Satellite Data Relay (ASDAR). ASDAR systems will be placed on wide-body aircraft (such as the B-747 and the DC 10) and will automatically transmit digital information on position, temperature, and wind direction and speed to geostationary satellites and subsequently to ground stations for processing. The feasibility of the aircraft-satellite link has been demonstrated and a prototype system is being built by NASA. This system is scheduled to undergo an international test during 1977 and a WWW prototype deployment during the FGGE observing period.

Special FGGE observing systems covering both the equatorial tropics and the Southern Hemisphere are needed to more completely describe the global state of the atmosphere. Theoretical studies and numerical experimentation have demonstrated a critical need for direct wind measurements with high vertical resolution in the equatorial zone (about 10°S to 10°N). In addition, reference-level data in the Southern Hemisphere are needed to complement temperature and moisture soundings from satellite radiance measurements. Ships, coupled with specially equipped aircraft, will help fill the gap in the equatorial zone. Each ship and aircraft will be capable of deploying newly developed wind-finding sondes. Constant level balloons will be launched to provide wind, temperature, and pressure-reference level data in the upper troposphere. In addition, a network of drifting buoys is planned to provide at least surface pressure and sea-surface temperature data in the Southern Hemisphere. These special observing systems will be implemented specifically for FGGE and will be especially important during the two FGGE observing periods scheduled for January-February and May-June 1979.

Nimbus 6, a research satellite, is also of value to FGGE planning because its infrared and microwave sounders provide nearly complete global coverage. Nimbus 6 sensors also measure the intensity and degree of polarization of emitted microwave radiation. These measurements provide information on parameters such as the liquid water content of clouds over water, distribution and variation of sea-ice, and moisture characteristics of land surfaces. Nimbus 6 has been a significant contributor to the DST, and two experiments on Nimbus 6 important to FGGE were available during the DST periods. A constant-level balloon experiment, TWERLE, provided information on wind, temperature, and pressure-reference levels; and the Earth Radiation Budget experiment provided data for investigating the earth's radiation balance, an essential part of climate studies.

Additional oceanographic and atmospheric observations during the FGGE are planned in connection with regional experiments, such as MONEX and POLEX, and also in support of national and international climate program objectives. Experimental satellites are planned to be launched during the FGGE observational period and are expected to provide valuable additional data.

International Plan

■

During its twenty-seventh session in May 1975, the WMO Executive Committee approved the time schedule for the FGGE observational period calling for a build-up phase beginning in September 1977, followed by an operational phase beginning in September 1978 and lasting for a full year. Two periods during January-February

1979 and May-June 1979 have been designated for intensive observing. FGGE special observing systems, described earlier, are planned for operation during these periods.

The WMO Intergovernmental Panel on the FGGE acts as the focal point for all activities relating to the detailed planning and implementing of the global experiment. At its second session in September 1975 the Panel adopted a general schedule of major international activities to guide and coordinate the activities of all countries and organizations involved in the planning for the FGGE. A requirement was identified for two major categories of detailed international implementation plans. The first category of plans emphasizes those aspects which must be specified well in advance of the build-up phase and should be completed and adopted by the FGGE Panel during its third session in July 1976. These include identifying specific responsibilities of participating countries and organizations, critical interfaces between activities, and plans for sub-system and interface tests. The second category is directed toward detailed aspects of the operational phase, which cannot be determined until more information is available and the operational date is more imminent.

The GARP Activities Office (GAO), established within the WMO Secretariat to provide day-to-day international planning and coordination of the FGGE, has been very active in planning formal and informal meetings on all aspects of FGGE. A worldwide Intergovernmental Planning Meeting was held in February 1976 primarily to obtain commitments from countries and organizations for the various sub-systems and components comprising the FGGE. The contributors of nearly all major components of FGGE have now been identified, and firm commitments are expected during the coming months.

Planning work was accelerated during the past year to define more clearly the procedures needed for an effective FGGE data management flow. In April 1975 an international meeting of experts was held in Washington, D.C., to develop a FGGE data management plan. Additional details of the FGGE data management flow were generated by the WMO Intergovernmental Panel on the FGGE at its second session in September 1975 and the Joint Organizing Committee at its eleventh session in October 1975. A series of meetings on specific segments of the total data flow, which require more detailed definition, was held in February 1976 and culminated in a second international meeting of experts on FGGE data management in May 1976.

Operational data sets required for FGGE will be produced and archived by the WMCs as part of their responsibilities within the WWW system. FGGE research data sets will be produced by a number of organizations. In particular, collection of a complete set of observations, including data which miss operational deadlines, will require the cooperation of the WWW and a number of countries and organizations. As many as nine research organizations are expected to be involved in the production of research analyses for FGGE. All FGGE research data sets will be archived in the WDCs.

■

U.S. Participation

The U.S. Federal Committee for Meteorological Services and Supporting Research established guidelines for the agencies participating in the FGGE and assigned leadership responsibilities for overall program coordination to NOAA, preliminary planning on FGGE to NASA, and university support of FGGE-related activities to NSF. In October 1974, NOAA established the U.S. FGGE Project Office as the interagency organization responsible for coordinating U.S. participation in FGGE and preparing detailed implementation plans. In addition to conducting the

Data Systems Test, NASA prepared a U.S. Plan for Participation in FGGE, which identifies current U.S. intentions to participate in FGGE and the responsibilities of U.S. organizations. NSF is continuing to work with university groups to ensure maximum participation of U.S. scientists in FGGE research planning activities.

The main U.S. contributions to the observing systems for FGGE are the continued implementation and operation of U.S. components of the WWW, including two operational geostationary satellites (GOES) and a new generation of operational polar-orbiting satellites (TIROS-N); the provision of technical and financial assistance to developing countries under the Voluntary Assistance Program to improve the WWW in areas with major deficiencies in observing and telecommunications; and the development and implementation of an aircraft dropsounding system to obtain direct wind observations in the equatorial tropics. The United States has conducted important development work on constant-level balloons (TWERLE) and drifting buoys in association with the NASA NIMBUS 6 satellite system, and the information will be valuable to the countries participating in the FGGE Southern Hemisphere special observing systems. NASA's experimental satellite program is planned to contribute important observations required for FGGE.

United States participation in processing, analyzing, and archiving the FGGE data will be equally important to the success of FGGE. To the extent possible, the agencies responsible for observing systems will acquire and process the data into meteorological parameters and communicate the data over the GTS for operational use by NMCs throughout the world. In the United States the NMC plans to expand its operations during the FGGE observational period to make global analyses and forecasts of several days duration using as much of the new data as possible. United States agencies also plan to produce, in delayed time, complete data sets for their respective satellite and special observing systems and to forward the data sets to an international organization responsible for producing the FGGE research data set. The Geophysical Fluid Dynamics Laboratory (GFDL) of NOAA plans to perform routine delayed analyses of the FGGE archives. The National Climatic Center of NOAA plans to archive and make available for worldwide distribution all operational and research data sets produced by countries and organizations participating in FGGE, including those produced by NMC and GFDL.

Perhaps the most critical U.S. participation in FGGE will be in planning and conducting research and numerical experimentation using the FGGE data sets. A number of U.S. institutions plan significant research efforts, including the National Center for Atmospheric Research supported by the NSF, universities such as UCLA, the Goddard Institute for Space Studies of NASA, and the NMC and GFDL of NOAA. NSF will supplement programs of the major modeling groups by supporting activities of the individual scientists who will use the FGGE data sets.

GARP Climate Objectives ■

The problem of understanding climate and climatic fluctuations was highlighted in the first chapter of the World Weather Program Plan for Fiscal Year 1976. The GARP climate activities are cast in the broader picture of the impacts that climate fluctuations have on practically all aspects of life. An ability to understand and predict the variations of climate would provide an important input to policy decisions concerning the production and distribution of food, water, and energy. It would allow a rational assessment of the possible climatic consequences of man's inadvertent or deliberate introduction of pollutants, heat, and other substances into the environment. The prospect of substantial progress justifies a concerted approach to the study of the many related problems. These include relationships between climate and food production, energy use, and assessing costs and benefits associated with various policy alternatives. The utility of various kinds of climatic information and forecasts also should be assessed. Broad international programs such as the United Nations Environment Program encompass many of these questions. As a result of the World Food Conference, the Food and Agriculture Organization and the World Meteorological Organization are jointly planning a Global Information Early Warning System on Food and Agriculture. National programs are under consideration in various forums within the United States Government.

■

Climate Dynamics

Considerable planning has been done during the past year to define the scope and form of the international GARP Climate Dynamics Subprogram. Important milestones in this effort include the April 1975 publication of the report of the 29 July - 10 August 1974 International Study Conference in Stockholm entitled "The Physical Basis for Climate and Climate Modeling; GARP Publication Series No. 16, April 1975." This document was designed to serve as a basis for the close international cooperation required to address the global problem of climate and climatic change. The document outlined in detail problems on all time scales that need to be solved; it also outlined the expanded research effort needed to solve the problems. The broad spectrum of processes that influence climatic fluctuations over the full range of time scales is illustrated in the accompanying figure.

Following publication of the 1975 report, additional meetings were held to focus the objectives of the international GARP climate activities. Recommendations were made that the GARP Climate Dynamics Subprogram concentrate on studying those processes important to understanding variations of the atmosphere-ocean system over time periods from about a month to a century. Priority has been given to developing dynamical and statistical models for those time scales. Even this focused problem is complex, and improved understanding of practically all components of the climate system shown in the figure is necessary.

The international climate program has two phases. The first, the latter part of the 1970s, is to be considered preparatory to the second, the full-fledged Climate Dynamics Subprogram to be implemented in the decade of the 1980s. Insuring that the FGGE data base contributes to the GARP climate objectives is an important part of the preparatory phase. Assembling historical data into useful climatic data sets also has high priority.

During the coming fiscal year, planning will continue for the international GARP Climate Dynamics Subprogram. An important facet of this planning will be interfacing this effort with related international programs such as UNEP, EARTHWATCH, and IGOSS.

Planning activities of U.S. agencies are just beginning for the GARP Climate Dynamics Subprogram. An ad-hoc committee of the Interagency Committee of the World Weather Program (ICWWP) has been charged with defining the program and insuring that U.S. GARP participation is an integral part of the overall U.S. climate program plan. A number of significant research programs already underway fall under the umbrella of the GARP Climate Dynamics Subprogram. These include efforts in NOAA, ERDA, NASA, and at NCAR to construct data sets and programs funded by Department of Defense, NSF, NOAA, and NASA to develop climate models. Coordination of these programs is one of the first tasks that needs to be done. The U.S. Committee for GARP has formed a climate dynamics advisory panel to guide and evaluate the overall national program. The comprehensive report entitled "*Understanding Climatic Change - a Program for Action*" published in 1975 by the U.S. GARP Committee of the National Academy of Sciences will continue to be the focal point for developing the national GARP climate activities.

SYSTEMS DESIGN AND TECHNOLOGICAL DEVELOPMENT ■

Global observations are required for both operational and research needs of the World Weather Program. These needs, especially for data from oceanic and remote areas, present major system and technological problems.

Technology under development to provide these data includes polar-orbiting and geostationary satellites and their associated sensor systems, constant level balloons, aircraft dropsonde systems, land-based remote-sensing devices, automatic meteorological observing stations, and data buoys. NASA, NOAA, NSF, ERDA, and the Department of Defense are participating in these efforts.

Synchronous meteorological satellites developed by NASA and operated by NOAA comprise the beginning of the U.S. system to provide nearly continuous imagery from geostationary altitudes for cloud information and a data collection subsystem for obtaining meteorological and oceanographic data from in-situ and mobile platforms. Currently, two satellites are in the operational mode and a third is in orbit on a standby status. NASA uses the NIMBUS satellite series as its primary polar-orbiting platform for testing research instrumentation, sensors, and data applications that might be used with NOAA's operational satellites. NIMBUS 5 has shown the advantages of the multi-spectral approach to improving sounding of the vertical structure of the atmosphere obtained by sensors on satellites. Both infrared and microwave techniques were used on NIMBUS 5 as opposed to the infrared mode only on NOAA's current operational satellites. The combined technique permits estimation of vertical profiles of temperature and humidity, not only in clear or partly cloudy regions but also in cloudy regions. NIMBUS 6, launched on 12 June 1975, includes advanced high resolution infrared sounders and a scanning microwave spectrometer. Data from these sensors provide an improved atmospheric sounding capability and an advancement of the multi-spectral concept.

Integral to the NIMBUS 6 program, NASA and NSF have jointly designed the Tropical Winds, Energy Conversion, and Reference Level Experiment (TWERLE). This experiment is attempting to determine the feasibility of making tropical wind measurements and establishing an atmospheric reference level in the Southern Hemisphere. Constant density balloons are used which incorporate random doppler-location techniques and a radio altimeter for height determination. This balloon system contributed significant data to DST in preparation for FGGE.

To keep pace with the needs of GARP and the WWW for environmental data, NASA and NOAA have initiated the joint development of a third-generation polar-orbiting satellite (TIROS-N) program. The current NOAA operational satellite (ITOS) is not large enough to carry the advanced operational version of present day instruments or the oceanographic and hydrologic instruments now being developed in NASA's research and development program. Those advanced instruments, with their improved resolution and accuracy, are needed to provide inputs into numerical models that form the basis for environmental monitoring, warning, and prediction programs.

The design and instrumentation of the TIROS-N system is a cooperative effort among the United States, the United Kingdom, and France. The detailed design of the spacecraft uses technology developed by both NASA and the Department of Defense. The United Kingdom is furnishing an infrared three-channel stratospheric sounding unit to provide information on the atmospheric region extending from 20 kilometers to about 50-55 kilometers. France will furnish a data-collection and platform-location system for installation on the spacecraft. The TIROS-N system will focus on providing quantitative data required by the improved numerical models in an effort to increase the accuracy of weather forecasts.

The TIROS Operational Vertical Sounder (TOVS) will provide more accurate and more frequent atmospheric temperature and water vapor profiles than are presently obtained from the Vertical Temperature Profile Radiometer system. Additional infrared spectral channels will increase the probability of obtaining measurements in the troposphere (the lower 10 to 20 kilometers of the atmosphere) and the stratosphere. TOVS will also incorporate a microwave channel to facilitate, within limits, observations through clouds.

The increased observational coverage and improved data accuracy are necessary to improve service to the public. The Advanced Very High Resolution Radiometer (AVHRR) is being designed to improve the ITOS service by increasing the accuracy of sea-surface temperature measurements. Knowledge of sea-surface temperature gradients permits monitoring of the locations of major ocean currents and upwellings. These factors are important to shipping and commercial fishing interests. The AVHRR also will provide information useful in differentiating clouds, snow and ice, and liquid water. Monitoring the snow-melt over remote river basins by comparing AVHRR observations in the visible and infrared channels will improve forecasts of snow-melt runoff for water management assessments of flood potential.

The National Oceanic and Atmospheric Administration also uses remote sensing techniques in its surface-based research and development program for land and ocean in-situ observing platforms. Microwave doppler radars using advanced frequency modulation and continuous wave techniques are looking at the structure and motion of the atmosphere in all weather situations. Development and field testing of acoustic sounders to provide temperature, wind, and humidity measurements in the lower atmosphere are continuing. Data are being collected and analyzed from backscatter, over-the-horizon radar to determine sea state over the North Pacific.

Other techniques, such as laser beams and LIDAR, are also under investigation by NOAA to provide meteorological and oceanographic data. NOAA is continuing tests on self-powered remote automatic meteorological observing stations equipped for telecommunicating some of the meteorological information previously available only from manned stations.

The National Oceanic and Atmospheric Administration is developing and field-testing buoy systems in support of operational and research meteorological and oceanographic programs. Emphasis during this period is on the development, fabrication, and deployment of drifting and ice buoy systems and a family of continental shelf buoys. These buoys will provide data from estuaries and the continental shelf for merchant shipping, fishing activities, marine recreation, and coastal habitation. Instrumentation research is centered on obtaining a capability to remotely sense the atmosphere from a buoy platform and on improving ocean profilers, meteorological sensors, and water quality and wave measurement instruments.

The National Oceanic and Atmospheric Administration on a routine basis conducts a wide variety of studies on applications of meteorological data to improve meteorological services. Special attention is directed toward developing new methods for applying satellite data to environmental analysis and forecasting.

The Energy Research and Development Administration is conducting fundamental studies in instrumentation, such as aerosol generators for testing particle samplers used in high altitude applications. Other techniques for investigating baseline levels of various pollutants are also under development.

3. The United States Program for Fiscal Year 1977

The World Weather Program comprises three areas of activity:

- World Weather Watch Implementation
- Global Atmospheric Research Program
- Systems Design and Technological Development.

The following conventions have been used to identify funds for U.S. activities in support of or contributing to the World Weather Program:

—Funds indicated without parentheses are for projects specifically in support of the World Weather Program.

—Funds indicated in parentheses have been designated by the Federal agency primarily to support programs that meet immediate mission needs, but at the same time fulfill a requirement of the World Weather Program, and would be budgeted even without U.S. participation in the World Weather Program.

—Funds for transitional quarter (July through September 1976) are not included in this section, but they are shown in Section 4 along with those for FY 1976 and FY 1977.

WORLD WEATHER WATCH IMPLEMENTATION

During FY 1977 the U.S. program will focus on maintaining a continuous, two-spacecraft, operational geostationary satellite system and procuring long-lead-time spacecraft and ground equipment for the next generation polar-orbiting satellite system. Assistance will also be provided to developing nations to enable them to participate in the World Weather Program.

Satellite Observing

The polar-orbiting satellite system provides cloud imagery and quantitative measurements of environmental variables twice daily in support of environmental monitoring and prediction programs. With two spacecraft the operational geostationary satellite system provides nearly continuous observations of environmental phenomena over most of North and South America and major portions of the Atlantic and Pacific Oceans for more effective warning services. The United States has capitalized on these observations and has initiated a major national system of Satellite Field Service Stations which generate and distribute specialized products.

DOC
($84,397,000)
NASA
($13,100,000)

NOAA 4, the most current spacecraft in the polar-orbiting ITOS series, was launched on November 1974. GOES 1, the first NOAA funded geostationary satellite, was launched on 16 October 1975 and replaced the Synchronous Meteorological Satellite (SMS) launched by NASA on 17 May 1974.

The Department of Commerce budget figures include offsetting program reductions of $2,691,000 as a result of completing initial phases of TIROS-N and $5,026,000 from the completion of the GOES B launch vehicle funding.

Major program efforts for FY 1977 will provide for:

–staff and contractor support for the TIROS-N series ground system
–continued procurement of ITOS and TIROS-N series spacecraft and instruments
–initial procurement of TIROS-N series launch vehicles
–launch services for ITOS H
–continued procurement of GOES series spacecraft and instruments
–launch services for GOES B and GOES C spacecraft.
–operation of both polar-orbiting and geostationary satellite systems.

The NASA is developing the TIROS-N, a third generation polar-orbiting satellite system, to meet stated requirements of NOAA for obtaining quantitative data of the earth's atmosphere on a daily basis. This new system scheduled to be launched early in 1978 will include an improved atmospheric sounder with microwave channels to facilitate data retrieval in cloudy areas, advanced multi-channel imagery, and addition of a data collection and platform location capability. Satellite-related efforts will also focus on the completion of the SMS/GOES Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder instrument which will be on GOES D. Efforts will continue on the definition of an Earth Radiation Budget Satellite System and the spare components of a comprehensive climate program. The development of a precision solar constant monitor for the Solar Maximum Mission will also be started.

Surface Observing

DOC
($2,440,000)
DOT
($4,757,000)

The Department of Transportation (U.S. Coast Guard) will provide ships to man ocean weather station Hotel from 1 August 1976 to 15 April 1977. The USCG Cutter TANEY will be the primary vessel.

The Federal Plan for Environmental Data Buoys specifies an array of buoys to provide synoptic environmental data for use by the U.S. National Weather Service and the worldwide meteorological community in providing weather forecasts, storm warnings, and public advisories. Buoy data will assist marine environmental studies and will aid NOAA in supporting marine industries. The FY 1977 plan calls for the procurement of electronic components and sensors to refit five data buoys and the operation of a total of nine deployed buoys.

Foreign Assistance

DOS
$1,500,000

The Department of State provides funds for VAP from the annual Foreign Assistance Act appropriation. Except for a direct cash donation to WMO of $150,000, the funds are administered by the Department of Commerce. A total U.S. contribution of $1,500,000 has been requested for this program in FY 1977.

These funds will be used by the United States to provide equipment, services, and fellowships to developing countries. Under this year's program, radio transmitting and receiving equipment will be made available for improving national and international meteorological data exchange; wind-finding radar will be provided in tropical areas for wind data acquisition; and a start will be made to implement plans for a direct readout station in South America for receiving GOES imagery. Long-term and short-term fellowships will be provided to meteorologists in developing countries to increase their capability to use modern equipment and to improve their understanding of atmospheric processes that result in weather and climate change. The United States will also supply kits for earlier recipients of Automatic Picture Transmission equipment under the VAP to improve their capability to receive direct readout transmissions from NOAA satellites and to provide a capability for intercepting processed data from the GOES system.

The Coast Guard Cutter YOCONA is shown towing environmental buoy 01 to station. This and sister cutters are equipped to place and service the operational buoy system being procured to obtain meteorological and oceanographic data.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM

During FY 1977 many activities will be conducted to further the goals of the Global Atmospheric Research Program. Data from the field observational phase of the GARP Atlantic Tropical Experiment, conducted during the 1974 summer season, and the recently completed Data Systems Tests will be processed, analyzed, and interpreted. International efforts to define the research required to advance knowledge on the physical basis of climate and climatic fluctuations will continue. Plans drawn for U.S. participation in the First GARP Global Experiment beginning in late 1977 will be amplified and a start made toward implementation. Research efforts in numerical modeling of the atmosphere and in global monitoring and analysis of critical environmental parameters will be continued.

Experiments and Analysis

DOC	**$6,454,000**
NASA	**$1,830,000**
NSF	**$5,618,000** **($5,460,000)**

The National Academy of Sciences U.S. Committee for GARP acts in an advisory role and recommends research programs including field projects that contribute to GARP objectives. The National Science Foundation and the National Oceanic and Atmospheric Administration provide equal support to this committee.

During FY 1977 the Department of Commerce will concentrate on (1) processing, analyzing, and archiving data collected during the field phase of GATE, (2) using the results of the Data System Tests to plan for FGGE, and (3) implementing FGGE. Compilation of GATE data sets will continue, and the results will be made available to the international scientific community as the work is completed. Research initiated during the past year to provide new and improved insight on the formulation of tropical processes in global atmospheric models will be continued.

The Department of Commerce will begin implementation of its participation in the First GARP Global Experiment. This initiative will include coordinating scientific programs; developing mathematical models and data management systems to accommodate the FGGE data; and specifying, developing, and procuring special observing systems, including environmental data buoys and special systems to provide supplementary wind observations in the tropics.

During FY 1977 NASA will continue to evaluate results of the Data System Tests in preparation for the FGGE. The last extended data collection test period ended in March 1976. Data from NIMBUS 6 and TWERLE were collected, and individual data collection and processing systems were tested. Meteorological observations extracted from aircraft flight information data systems were also included. NASA will also continue to participate in the analysis phase of GATE by providing data processing facilities.

In FY 1977 the National Science Foundation will continue to support the analysis and interpretation of the data collected during the GARP Atlantic Tropical Experiment (GATE) and the Air Mass Transformation Experiment (AMTEX). The NSF will also continue its support of the Polar Experiment (POLEX), the Monsoon Experiment (MONEX), and the Indian Ocean Experiment (INDEX), a planning program in support of the oceanographic part of MONEX.

The National Science Foundation and the Department of Commerce have agreed to support university research utilizing GATE data. Therefore, many of the grants will be jointly funded by NSF and the Department of Commerce with grant administration provided by NSF.

Atmospheric Modeling and Simulation

DOC	**($8,882,000)**
DOD	**($1,040,000)**
ERDA	**($1,070,000)**
NASA	**$4,170,000**
NSF	**$3,751,000** **($2,685,000)**

A significant research program to develop numerical models of the global atmosphere is being conducted by a number of Federal agencies, several universities, and NCAR. Although several models are now operational, further refinement of these models is needed to reproduce atmospheric motions with greater fidelity to determine the ultimate limit of weather predictability, to assess the effect of man's activities on climate, to develop methods for using nonsynchronous data as bases for predicting large-scale motion, and to design an optimum composite meteorological observing system for routine numerical weather prediction.

During FY 1977 ERDA is continuing its effort to develop a comprehensive model for estimating long-term air concentrations of and resultant population exposure to pollutants injected into the atmosphere from anywhere on the globe. Such a model is needed to evaluate the effects of alternative means of energy production on local, regional, and world populations.

Analyses of stratospheric concentrations of radioactive debris from nuclear weapons tests will be continued to provide data to assist in developing numerical global circulation models. A simple circulation model based on the flux-gradient relationship has been developed, and the estimated distribution of radioactive materials from recent high yield nuclear tests will be used as input to determine the model's limitations in estimating depletion and/or build-up of possible man-made contaminants in the stratosphere. Investigations are also being conducted to assess the vulnerability of the stratosphere, with respect to changes in ozone concentration, resulting from injections of fluorocarbons and oxides of nitrogen.

Studies are being conducted to understand the atmospheric and oceanic budgets of energy, angular momentum, and mass and to apply this understanding to problems of the global distribution of trace substances, both active and passive, so that the complete cycle of these trace constituents can be outlined.

The Department of Commerce in FY 1977 will conduct fundamental investigations of the dynamics of geophysical fluids, the atmosphere, the hydrosphere, and the cryosphere over a wide range of time and space scales. Much of the research program is conducted at the Geophysical Fluid Dynamics Laboratory using a fifth-generation computer. This computer provides the basis for employing new models with improved physical characteristics and improved computational resolution.

A new atmospheric general circulation model, which will among other things predict extended areas of cloud cover, will be used for long-term integration with imposed seasonal variations. This model will also be used for simulations of climate based on paleoclimatology reconstructed for 18,000 years ago. These simulations are part of the on-going effort to determine the sensitivity of climate models to various conditions. Tests of the Mellor-Yamada boundary layer parameterization technique will be performed to study its effects on theories of the sub-tropical boundary layer, the maintenance of the sub-cloud inversion, and its influence on the vertical exchanges in the free troposphere. A series of one-month extended forecast experiments will be performed with a global, general circulation model using the global data sets of November 1969, the 1974 GATE data set, and the FGGE Data Systems Test of August 1974. Parameterization studies will also be performed to test alternative means of representing cumulus convection and boundary layer turbulence. Observational studies of the global oceanic structure will be undertaken to determine the heat and salinity balances and, if possible, their interannual variations. A new, three-dimensional model for deep moist convection will be applied to determine the effects of convection upon the mean wind and the mean vertical profiles of temperature and water vapor. A new, three-dimensional hydrostatic model, appropriate to the coastal oceans, which can respond to tidal forcing, winds, and surface temperature and salinity fluxes will be applied to problems associated with continental shelf areas of the northeast coast of the United States.

The Department of Defense in FY 1977 will continue its global atmospheric modeling program. This includes studies of frictional effects, topography, and radiation; the physical processes that contribute to the formation of organized atmospheric circulations; the ocean-atmosphere environment as a single entity; and sea-air interaction and energy balance.

During FY 1977 NASA, with the support of NOAA, NSF, and other groups, will continue to conduct tests of data utilization to determine the limitations and difficulties in the preparation of global data sets with the coverage and accuracy required for FGGE. The objectives of these tests are to provide system designers with information on the overall performance and effectiveness of observing systems and the consequent handling and processing of the data. The Goddard Institute for Space Studies will conduct theoretical studies and real-time data experiments for the optimization of satellite observing systems, extraction of maximum meteorological information from spaceborne sensors, and application of this information to improved numerical prediction of atmospheric processes.

The National Science Foundation will continue to support GARP-related research at universities and at NCAR to improve numerical modeling and conduct studies of predictability. The modeling efforts being supported include models of turbulence, boundary layer phenomena, large-scale prediction, cumulus convection parameterization, and the general circulation. Predictability studies range from the most basic, analytic studies of the equations of motion and energy to examination of the statistical response of the NCAR general circulation model to a variety of perturbations.

Many studies supported by NSF combine numerical modeling and observational analysis and interpretation to enhance the overall understanding of the global atmospheric-oceanic system. One goal of the Global Extended Range Prediction System is to improve the accuracy of forecasts over ocean areas for longer periods of time, initially to 72 hours and later to 10 days and beyond. Evaluation and selection will continue of numerical models of the atmosphere, ocean, and ionosphere which deal with exchange processes and the distribution of significant characteristics of the air-sea interface and of the marine planetary boundary layer.

The NSF-sponsored modeling research includes such diverse efforts as validating a detailed, meso-scale, air-sea boundary layer model using BOMEX and GATE data; applying the entire general circulation model to examine atmospheric responses to sea-surface temperature anomalies, as well as other perturbations in the forcing function; and developing and testing cumulus parameterizations for large-scale models.

National Science Foundation grantees are using model simulations to plan observation programs for MONEX and FGGE. For example, meteorologists and oceanographers are working together to analyze models and use the results to examine the atmosphere, land, and ocean interactions involved in the perturbations of the Somali current in the southwest monsoon. These studies will be used in planning, analysis, and interpretation for MONEX.

Global Monitoring and Climate

NSF
$240,000
($815,000)
DOC
$325,000
($1,462,000)
ERDA
($1,893,000)
EPA
($6,000,000)
DOT
($300,000)
NASA
($9,800,000)

The United States is conducting programs to monitor atmospheric constituents, including trace elements, to determine their influence on climate as well as their impact upon the quality of the environment.

The ERDA is conducting measurements of the monthly fallout rate of radionuclides by sampling at about 125 land stations throughout the world. Data are used to study the global fallout rate of strontium-90 and to determine the latitudinal deposition increments for assessing the fallout inventory. This program is the only one now operating on a worldwide basis. Deposition of a number of stable trace metals is being studied in New York and San Francisco. These studies have been extended by installing instruments at the Department of Commerce's baseline station at Mauna Loa to investigate baseline levels of various pollutants. Data are also accumulated on surface air concentrations of stable lead through a complete range of pollution levels from Mauna Loa to some of the most contaminated urban centers in the Western Hemisphere. The high altitude sampling program will be conducted by aircraft from 75°N to 10°S in the Western Hemisphere and by balloons launched from Panama, Alaska, and New Mexico. These sources will provide data on selected radioactive particulates from about 12 to 27 kilometers.

A wide spectrum of radionuclides is being measured on a continuous basis at the remotely located air monitoring station at Quillayute, Washington. Stable elements are also being measured daily to determine their variations and concentrations with time. Ground-level sampling of atmospheric tritium and tritiated water vapor will be continued on a twice weekly schedule at Mauna Loa, Miami, and Fairbanks; a fourth station is proposed for Tasmania, Australia.

The FY 1977 program for the Department of Commerce will include operating the expanded facilities for more accurate sampling of fluorocarbons, initiating LIDAR experimentation at Point Barrow, testing an improved solar radiation system, and modernizing the facility at the South Pole station. The Department of Commerce will conduct research on cause-and-effect relationships between climate and atmospheric pollutants and will attempt to identify sources and trends of the various polluting materials.

In FY 1977 the Department of Transportation, through the FAA's High Altitude Pollution Program (HAPP), will continue to study the effects of aircraft exhaust pollutants injected into the stratosphere. As part of this program, measurements will be made in the stratosphere of various species such as methane, nitrous oxide, nitric oxide, nitrogen dioxide, nitric acid, and ozone. Developmental work will begin on instruments for the simultaneous in-situ stratospheric measurement of species such as those just listed. Support will be given to global monitoring activities, which are primarily the responsibility of other agencies. To improve its capability to predict stratospheric effects due to aircraft exhausts, the Department of Transportation will support improvements of dynamic models that couple stratospheric transport and stratospheric chemical interactions. These research activities are being done in cooperation with the Department of Commerce, the Department of Defense, ERDA, EPA, NASA, and NSF in the United States and with several foreign countries as well.

The Environmental Protection Agency (EPA) will continue its regional air pollution study in FY 1977. The purpose of the study is to develop and calibrate diffusion and prediction models for determining the atmospheric, chemical, and physical transformation of pollutants emanating from stationary and mobile sources. EPA is also developing a remote-sensing capability for determining pollutant profiles, estimating mixing depths, measuring thermal stability of the lower atmosphere, and for special events. A light aircraft fitted with pertinent scientific equipment is being used by EPA for this purpose.

During FY 1977 NASA will continue developmental work on remote sensors for monitoring atmospheric composition and pollutants from space. Special sensors for determining both gaseous and particulate pollution are being developed and tested for experimental use on Nimbus G, scheduled for launch in 1978. Advanced atmospheric sounders proposed for the Nimbus G spacecraft include instruments for measuring the trace constituents and particulates in the atmosphere from the troposphere upward into the mesosphere on a global basis to assess the feasibility of space-mapping and predicting atmospheric pollution. NASA is also conducting studies and in-situ observations directed toward developing techniques for defining and predicting the global distribution of minor constituents in the atmosphere and the effects that changes in this distribution would have on the physical state of the atmosphere. Of particular interest are the effects of contaminant injection into the stratosphere; the emission and dispersal of pollutants and natural trace gases on urban, regional, and global scales in the troposphere; and possible climatic changes resulting from variations in minor constituent concentrations. NASA will conduct concurrent investigations into (1) atmospheric chemistry and physics, leading to the development of dynamic models coupling chemical reactions, atmospheric dynamics, and pollutant diffusion, and (2) atmospheric sensing to provide real data for the mathematical models. The resulting combinations will then be used in experiments to define and predict the time-dependent concentrations and transport of atmospheric pollutants.

In FY 1977 the design and development of the advanced version of the High Speed Interferometer (HSI) will be initiated. The HSI will have the capability to make global measurements of lower atmospheric (tropospheric) and upper atmospheric (stratospheric) trace gases with absorption bands in the infrared spectral range. This sensor will make it possible to determine baseline values for stratospheric constituents and their concentration.

The National Science Foundation supports a variety of global monitoring efforts. As part of the International Decade of Ocean Exploration (IDOE) program, scientists working with the North Pacific Experiment (NORPAX) will study long-period, large-scale ocean-atmosphere coupling. Special efforts are being made in NORPAX to monitor the North Pacific Ocean and atmosphere. IDOE also supports the International Southern Oceans Studies (ISOS), which monitor oceanic transports through the Drake Passage. The NSF Meteorology Program supports the observation and analysis of carbon dioxide in Hawaii and in the Southern Hemisphere. The Office of Polar Programs at NSF supports a NOAA baseline station at the South Pole, which collects data on carbon dioxide, ozone, and aerosols. NSF also supports the daily surface and upper air observations made at the South Pole and McMurdo stations and transmitted routinely to the WWW.

SYSTEM DESIGN AND TECHNOLOGICAL DEVELOPMENT ■

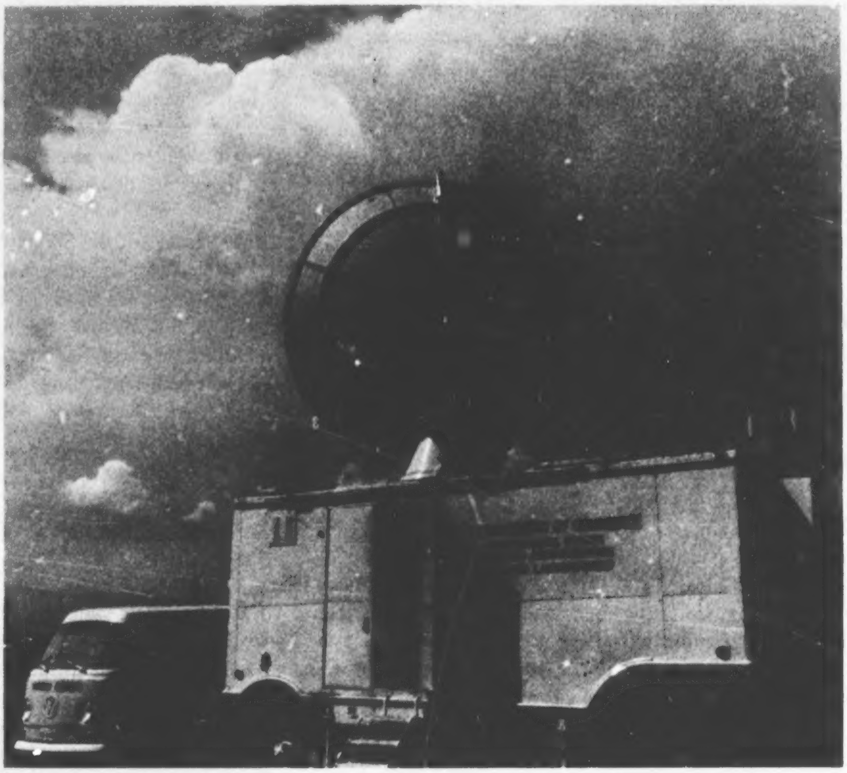
Instrument Development

DOC
($2,903,000)

The United States will continue a comprehensive program to provide the means for implementing the WWW and conducting GARP field experiments.

The Department of Commerce's comprehensive program to develop ground-based techniques for the remote measurement of critical meteorological and oceanographic parameters required by service and research programs will be continued during FY 1977. NOAA conducts research to devise and develop new concepts of instrumentation for environmental measurements with primary emphasis on remote sensing and automation. Prototypes of various NOAA configurations of acoustic sounders are being evaluated by NOAA, the Department of Defense, the Department of Transportation, and EPA. Field experiments using LIDARS are being conducted to develop techniques to measure particulate pollutants and to study cloud processes. An over-the-horizon radar recently constructed at San Clemente, California, will be used to determine the practicality of remotely measuring sea state in the North Pacific. New doppler radars under advanced development measure three-dimensional wind fields continuously in severe storms. Field experiments employing lasers are being conducted to measure profiles of temperature, humidity, and gaseous pollutants. Optical techniques for continuously measuring average horizontal winds across long paths have been demonstrated and are under further investigation. Other projects include the development of modular automatic stations and associated sensors for use in remote unmanned locations and aboard ships.

DOT
($1,200,000)
ERDA
($264,000)
DOD
($345,000)



Doppler radar techniques are being developed to provide more information on the dynamics of storm systems. By tracking rain drops, for example, wind velocities can be inferred and thus provide meteorologists with better information on storm development and intensity. Doppler radars have long been used for research and are now being evaluated for operational use.

The Department of Defense is developing sensor instrumentation for aircraft, ships, and automatic weather stations which will contribute to the GARP experiments and WWW, although not directly a part of either effort. In FY 1977 the Department of Defense efforts will be directed toward improving ground, shipboard, and airborne meteorological sensors; developing airborne refractometer systems for sensing and recording atmospheric refractive-index profile data; investigating sensing techniques for direct measurement from aircraft; and developing a remote wind sensor utilizing a laser. A cloud height visual range set is also under development.

The Department of Defense is also developing a miniature radiosonde which will measure temperature, pressure, and humidity profiles of the marine atmosphere. The instrument will provide data of adequate quality for determining atmospheric refractive-index profiles. The self-contained, lightweight radiosonde will be launched with a 30-gram balloon from ships at sea. The operational test and evaluation of this system is scheduled for FY 1980.

The Department of Transportation is continuing to direct and fund a program being conducted by the National Weather Service to develop a totally automated aviation weather observation station. This station will provide digital readouts of wind direction, speed and gusts, altimeter setting indications, temperature, dew point, visibility, cloud height, cloud cover, and present weather.

The ERDA is conducting fundamental studies to support the development of several instruments for its high altitude sampling program. An electrostatic band-pass aerosol generator for use in testing particle samplers and an improved electrostatic precipitator for high-altitude application are being developed. Studies are also being continued concerning the application of molecular sieves to sample stratospheric trace gases.

The Department of Commerce, the Department of Defense, and NASA have jointly initiated a project to develop a sensing system for deployment from aircraft to obtain upper atmosphere temperature and wind profiles in tropical areas. This effort is directed primarily toward the special observing requirements of FGGE and will be used in conjunction with conventional balloon systems and tropical wind-finding ships. Components of systems used during GATE and by the Department of Defense for weather reconnaissance will be adapted for this FGGE system. New work will concentrate on improving data processing and data communication.

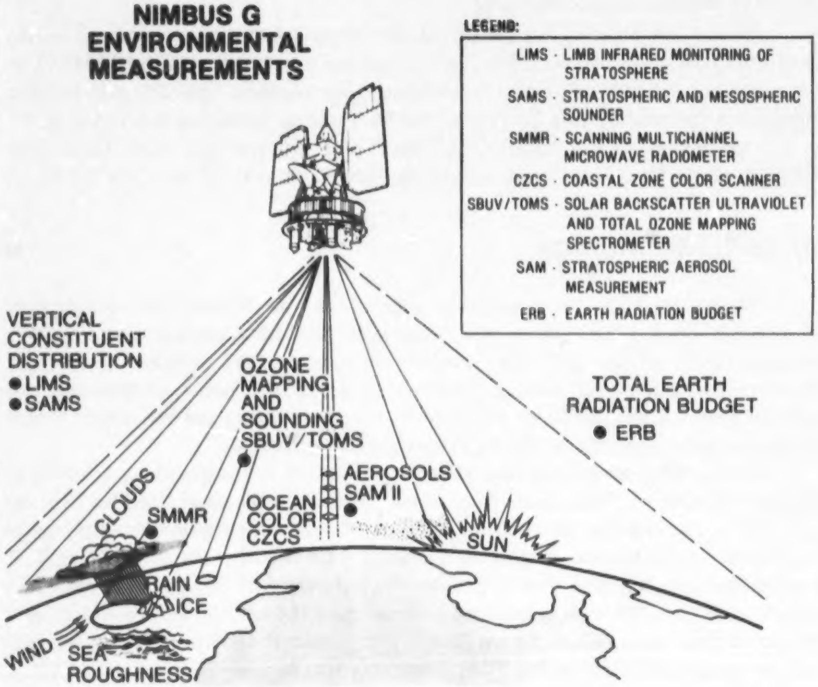
Buoys

DOT
($1,251,000)
NSF
$172,000
($150,000)
DOC
($5,027,000)

During FY 1977 the Department of Commerce will continue developing, procuring, operating, and maintaining buoy platforms to acquire data in support of basic environmental service programs. These buoys will provide measurements of wind velocity, air temperature, barometric pressure, wave height and period, and subsurface water temperature at six levels. Prototype operational buoys capable of collecting surface meteorological and limited oceanographic data were deployed off the west coast of the United States during 1975 and early 1976. The design of these buoys utilized the extensive experience gained from the experimental data buoys deployed over the past several years in U.S. coastal waters. The Department of Commerce will continue developing additional buoy systems to satisfy ocean-monitoring and marine weather service programs.

NSF and the Department of Commerce emphasis in future development is on drifting and ice buoy systems; remote sensing of the lower atmosphere from buoy platforms; water quality sensors; and improving ocean profilers, meteorological sensors, and wave measurements. NSF, NCAR, and NASA will test an expendable drifting buoy system as a means to provide a pressure-reference level at the surface and surface-water and mixed-layer temperature. Most of these developments will have direct application to the WWW and FGGE. In addition NSF is supporting buoy development for the North Pacific Experiment.

The Department of Transportation, through its U.S. Coast Guard, provides support to the Department of Commerce Data Buoy Program for developing and evaluating data buoy systems. U.S. Coast Guard vessels deploy, service, and retrieve buoys built for test or operational purposes. Coast Guard radio facilities provide communication services serving as data buoy collecting sites.


NIMBUS G
ENVIRONMENTAL
MEASUREMENTS
LEGEND:
LIMS - LIMB INFRARED MONITORING OF STRATOSPHERE
SAMS - STRATOSPHERIC AND MESOSPHERIC SOUNDER
SMMR - SCANNING MULTICHANNEL MICROWAVE RADIOMETER
CZCS - COASTAL ZONE COLOR SCANNER
SBUV/TOMS - SOLAR BACKSCATTER ULTRAVIOLET AND TOTAL OZONE MAPPING SPECTROMETER
SAM - STRATOSPHERIC AEROSOL MEASUREMENT
ERB - EARTH RADIATION BUDGET
VERTICAL CONSTITUENT DISTRIBUTION
● LIMS
● SAMS
OZONE MAPPING AND SOUNDING SBUV/TOMS
TOTAL EARTH RADIATION BUDGET
● ERB
AEROSOLS SAM II
CLOUDS
SMMR
OCEAN COLOR CZCS
SUN
RAIN
ICE
WIND
SEA ROUGHNESS

The Nimbus G satellite is the seventh in the series of the Nimbus research satellites and is scheduled to be launched in 1978. The instruments onboard the satellite will make environmental measurements in the fields of pollution, monitoring, oceanography and meteorology.

■ Research and Development Satellites

The National Aeronautics and Space Administration's development of experimental meteorological satellites and associated sensors will continue to improve and expand the capabilities of the present national operational system. Data acquired from the experimental satellites provide essential information for research and operational meteorological purposes and will support the observational stages of the FGGE.

NASA
($38,100,000)

NIMBUS 6 is a test bed for new infrared and microwave instrumentation which should improve the determination of the atmospheric vertical structure in both cloudless and cloudy regions. This sun-synchronous, polar-orbiting spacecraft carries meteorological experiments consisting of scanning mappers, atmospheric sounders, and earth radiation balance sensors. Instrumentation for locating and collecting data from in-situ sensors will continue to support GARP through FGGE.

NIMBUS G, with a planned launch in 1978, is a multi-disciplinary satellite serving the application areas of pollution, oceanography, weather, and climate.

Fabrication of instruments and spacecraft will be accomplished in FY 1977 for the Sea Satellite (SEASAT) spacecraft. The Sea Satellite, to be launched during the first half of 1978, will be dedicated to ocean dynamics applications. Its mission will be to demonstrate the feasibility of acquiring data applicable to monitoring and predicting physical ocean phenomena.

Studies for defining the mission items unique to the 3-axis stabilized Storm Satellite (STORMSAT) spacecraft will be completed during FY 1977. STORMSAT as it is currently defined, will carry the Advanced Atmospheric Sounding and Imaging Radiometer instrument. This instrument will be a second generation radiometer based on the technology of the SMS/GOES Visible and Infrared Spin Scan Radiometer (VISSR) and the VISSR Atmospheric Sounder instrument that will be on GOES D.

Supporting Research and Technology

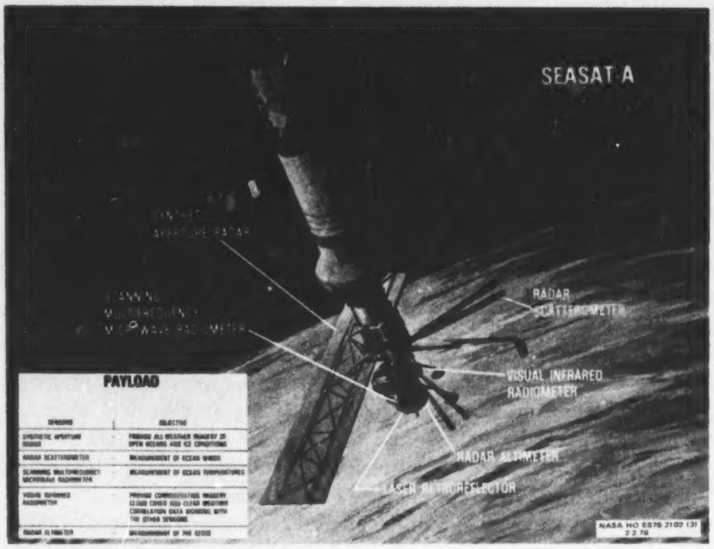
DOC
($5,363,000)
NASA
($32,100,000)

Major emphasis in supporting research is on deriving the quantitative information needed to develop new techniques for using satellite data. Specific programs involved are hydrology, marine forecasting, and weather forecasting. Encouraging results have been achieved in assessing the ocean environment for increasing fish yields, sea-ice surveillance on the Great Lakes and the oceans, ocean dynamics studies, and soil moisture and snow-pack assessment.

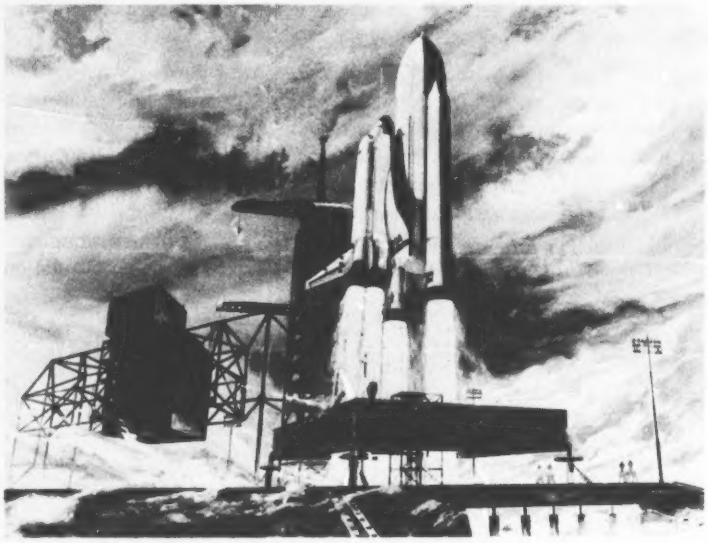
Forecasting oceanic surface weather conditions is hampered by a less than adequate number of observations from ocean areas. Environmental satellites have the potential to alleviate this situation. SEASAT A, the first satellite developed primarily to observe oceanic surface conditions, is scheduled for launch in the spring of 1978. It is estimated that SEASAT A will provide the equivalent of 20,000 to 80,000 ship reports each day. NASA is committed to developing the satellite and its sensors and placing it into orbit. When the satellite begins transmitting data, the program will become quasi-operational at the Fleet Numerical Weather Central Monterey, California, and will undergo evaluation for one year.

During FY 1977 the Department of Commerce plans to develop techniques for processing, analyzing, and applying data acquired by SEASAT. This effort includes development of models for observing and predicting ocean surface winds and waves, determination of sea level and sea slope, and acquisition of sea-surface temperatures from microwave data.

The Department of Commerce will also continue its efforts to improve the application of satellite data to environmental warning and forecast preparation. Emphasis in this effort is on developing global atmospheric and constituent profiling systems that can be utilized in numerical weather prediction models. Oceanographic and hydrologic sensors are also being developed for use on space and aircraft platforms to measure sea-surface temperatures, to outline sea-ice distribution, and to assess snow-pack and soil moisture content.



Artists' concept of NASA's new ocean surveying satellite, SEASAT-A, to be launched in 1978. Instruments aboard the satellite are indicated on the photograph and the sensor objectives are listed in the lower left-hand insert. The data will be provided to government agencies, institutions, universities and commercial users.



Artists' concept of the Space Shuttle launch at Kennedy Space Center, Florida, with the orbiter's three liquid-rocket engines and the two solid-rocket boosters generating a total of over 6.5 million pounds of thrust. NASA is conducting studies to determine which environmental programs could be conducted on-board the shuttle.

NASA research and development efforts in FY 1977 will continue in sensor development, sensor evaluation, and analysis and interpretation to extend the capabilities for measuring environmental parameters. Satellite observations will be applied to determine such meteorological phenomena as location of rain areas; vertical distribution of atmospheric temperature, humidity, and ozone; and cloud motions (winds) from geostationary satellites. The prime objective of this research is to establish a basis for specifying remote sensing needs of the global meteorological observing system required for both large-scale, long-term weather forecasts and short-term forecasts.

Sensor development is directed toward early identification of severe storms and the measurement of such parameters as atmospheric structure and composition, aerosol content, and surface conditions - including soil moisture, ice and snow cover, and sea state. Efforts to develop an operational geostationary imager/sounder capable of imaging and profiling mesoscale weather phenomena and an operational microwave temperature sounder for the next generation polar-orbiting satellite will continue during FY 1977. These sounders will improve the accuracy of temperature profiles retrieved from infrared soundings under partly cloudy conditions and will also permit soundings in the lower troposphere in the presence of extensive clouds.

Part of the NASA effort in sensor development for research spacecraft will be directed toward a geostationary 3-axis stabilized sounder/imager. Three-axis stabilization in geostationary orbit affords avantages that permit important improvements in sounding and imaging capability over that of a spinning instrument. Additional efforts are directed toward the development of advanced passive microwave radiometer technology for global surveillance of storms to determine such parameters as precipitation rate, liquid water content, and cloud height and structure.

The space shuttle program will influence and guide other flight missions in the near future. Studies to determine the optimum use of the space shuttle for meteorological applications will continue during FY 1977.

Stratospheric applications in FY 1977 will focus on the needs for monitoring the nitrogen-ozone and halogen-ozone chemical cycles. This work will be further supported by special sounding rocket launches as well as those from the standard meteorological rocket network. Studies will continue on post-Nimbus G pollution monitoring tasks using the spacelab. Second-generation multigas sensors, especially the Laser Heterodyne Spectrometer and the Measurement of Air Pollution by Satellite instruments, will be evaluated on local and urban scales as a part of the tropospheric program. Regional pollutant dispersion models will be coupled to global circulation models in support of future satellite missions.

4. Fiscal Summary

The United States has planned activities for FY 1977 in all major areas of the World Weather Program–World Weather Watch, Global Atmospheric Research Program, and Systems Design and Technological Development. Funding by various Federal agencies in these three areas is summarized below. Values shown indicate outlays for FY 1976 and amounts requested in the President's budget for FY 1977 and the transition quarter. Funding is categorized as either direct (specifically in support of the World Weather Program) or indirect (primarily for other agency needs, but also fulfilling a World Weather Program need).

(Thousands of Dollars)

		FY 1976		Transition Quarter		FY 1977	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
World Weather Watch Implementation	DOC		66,696		20,674		86,837
	DOS	1,500				1,500	
	DOT		3,767		1,189		4,757
	NASA		13,600		3,800		13,100
	Total	1,500	84,063		25,663	1,500	104,694
Global Atmospheric Research Program	DOC	6,635	10,171	1,701	2,494	6,779	10,344
	DOD		2,294		210		1,040
	DOT				75		300
	EPA		6,000		1,500		6,000
	ERDA		3,189		861		2,963
	NASA	7,000	8,100	2,000	3,350	6,000	9,800
	NSF	8,879	8,617	2,760	2,860	9,609	8,960
	Total	22,514	38,371	6,461	11,350	22,388	39,407
Systems Design and Technological Development	DOC		14,647		1,898		13,293
	DOD		325		106		345
	DOT				613		2,451
	ERDA		267		72		264
	NASA	168	59,232		18,050		70,200
	NSF	615	330	150	35	172	150
	Total	783	74,701	150	20,774	172	86,703
Totals by Agency	DOC	6,635	91,414	1,701	25,066	6,779	110,474
	DOD		2,619		316		1,385
	DOT		3,767		1,877		7,508
	DOS	1,500				1,500	
	EPA		6,000		1,500		6,000
	ERDA		3,456		933		3,227
	NASA	7,168	80,932	2,000	25,200	6,000	93,100
	NSF	9,494	8,947	2,910	2,895	9,781	9,110
	Grand Total	24,797	197,126	6,611	57,787	24,060	230,804

APPENDIX-LIST OF ACRONYMS

AFOS	Automation of Field Operations and Services
AHOS	Automatic Hydrologic Observing Station
AMOS	Automatic Meteorological Observing Station
AMTEX	Air Mass Transformation Experiment
ASDAR	Automatic Satellite Data Relay
AVHRR	Advanced Very High Resolution Radiometer
APT	Automatic Picture Transmission
BOMEX	Barbados Oceanographic and Meteorological Experiment
CBS	Commission for Basic Systems
CIAP	Climatic Impact Assessment Program
CIMO	Commission for Instruments and Methods of Observation
DOC	Department of Commerce
DOD	Department of Defense
DOS	Department of State
DOT	Department of Transportation
DST	Data Systems Test
EB	Environmental Buoy
EPA	Environmental Protection Agency
ERDA	Energy Research Development Administration
ESA	European Space Agency
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FGGE	First GARP Global Experiment
GAO	GARP Activities Office
GARP	Global Atmospheric Research Program
GATE	GARP Atlantic Tropical Experiment
GDPS	Global Data Processing System
GEMS	Global Environmental Monitoring System
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute for Space Studies
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GTS	Global Telecommunications System
HAPP	High Altitude Pollution Program
HSI	High Speed Interferometer
ICAO	International Civil Aviation Organization
ICSU	International Council of Scientific Unions
ICWWP	Interagency Committee for World Weather Program
IDOE	International Decade of Ocean Exploration
IGOSS	Integrated Global Ocean Station System
INDEX	Indian Ocean Experiment
IOC	Intergovernmental Oceanographic Commission
ISOS	International Southern Oceans Studies
ITOS	Improved TIROS Operational Satellite
LIDAR	Light Detection and Ranging
MONEX	Monsoon Experiment
MTC	Main Trunk Circuit
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NMC	National Meteorological Center
NPC	National Processing Center
NOAA	National Oceanic and Atmospheric Administration
NORPAX	North Pacific Experiment
NSF	National Science Foundation
NWS	National Weather Service
NWSRFS	NWS River Forecast System
POLEX	Polar Experiment
RMC	Regional Meteorological Center
RTH	Regional Telecommunication Hub
SDC	Subprogram Data Center
SEAS	Shipboard Environmental Data Acquisition System
SEASAT	Sea Satellite
SMS	Synchronous Meteorological Satellite
STORMSAT	Storm Satellite
TOVS	TIROS Operational Vertical Sounder
TWERLE	Tropical Wind, Energy Conversion, and Reference Level Experiment
UCLA	University of California at Los Angeles

UN	United Nations
UNEP	UN Environment Program
UNESCO	UN Educational, Scientific, and Cultural Organization
VAP	Voluntary Assistance Program
VISSR	Visible and Infrared Spin Scan Radiometer
WHO	World Health Organization
WDC	World Data Center
WEFAX	Weather Facsimile
WMC	World Meteorological Center
WMO	World Meteorological Organization
WWW	World Weather Watch
XBT	Expendable Bathythermograph

☆ U.S. GOVERNMENT PRINTING OFFICE : 1976 O—219-811